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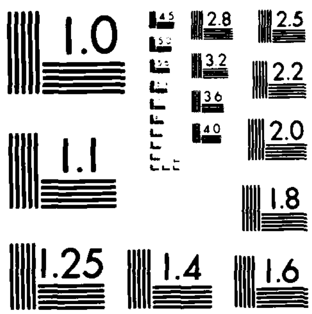

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US Army Corps of Engineers

St. Paul District

APPENDICES

Mississippi River

Headwaters Lakes in Minnesota

Feasibility Study

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The investigation of six Mississippi River Headwaters Lakes: Gull Lake, Leech Lake, Pine River, Pokegama, Sandy and Winnibigoshish, centers on all water resource problems involving the operation of Corps' dams. The study includes a review of lake operation plans for flood control, water supply, recreation, navigation, power, and conservation; review of erosion control problems downstream of Pokegama dam; review of bank erosion; a feasibility study of stabilized White Oak Lake water levels on the Mississippi River

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upstream of Pokegama and Leech Lake River; a review of flood problems near Riverton, Minnesota; a hydrologic review of the existing headwaters lakes perimeter diking system; a feasibility study of removing channel obstructions on the Whitefish Lakes Chain; a study of the adequacy of the Leech Lake inlet channel; a review of a possible subimpoundment in Leech Lake and marsh restoration; and a review of the adequacy and effectiveness of the existing flood control project for Aitkin, Pine Knoll and Cedar Brook.

The appendixes provide greater detail than the main report on the development of the alternatives and specific study aspects and include pertinent correspondence relating to study coordination activities among federal, state and local interests.

STAGE 3 SUMMARY REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

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APPENDIX B - HISTORY OF REGULATIONS FOR MISSISSIPPI RIVER HEADWATERS LAKES

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STAGE 3 REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

DESIGN CONSIDERATIONS AND DETAILED COST ESTIMATES

APPENDIX A

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

APPENDIX A

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INTRODUCTION

This appendix contains a summary of pertinent data used in evaluating alternatives involving 10 identified water resource problems in the Mississippi River Headwaters Lake Study. These 10 problems relate either directly or indirectly to the operation of the six headwaters lakes whose levels were raised by Corps dams constructed between 1881 and 1913. Recent national interest in the hydropower potential of existing dams precipitated additional analysis of this possibility for each headwaters dam.

Each of the 10 problems is addressed under a minimum of 5 principal headings involving background; geologic and soils information; hydrology and hydraulic studies; detailed estimates of first costs, annual costs, and benefits; and recommended action where appropriate. Plates are included at the end of the discussion for each problem.

PROBLEM 1 - HEADWATERS LAKES OPERATING PLANS

BACKGROUND

Between 1881 and 1913, the Corps of Engineers constructed six water control dams on lakes in the headwaters area of the Mississippi River, primarily to benefit river navigation with incidental benefits for logging. Most of the land bordering the lakes was originally owned by the Federal Government, and flowage easements were acquired on all other riparian lands. Much of the land owned in fee was later sold, although the Government reserved, and still retains, all flowage rights

on lands required for full operation of the lakes. All homesites, resorts, and commercial establishments on the shores of these lakes have been developed on lands leased from the Government or on privately owned lands subject to Government rights. A general map of the basin showing the six Mississippi River Headwaters Lakes is shown on plate A-1.

The need for water releases to aid navigation was greatly reduced by completion of a 9-foot navigation channel below Minneapolis in the 1930's. With the development of recreation as a business, recreation interests exerted constantly increasing pressure on the Government to stabilize water levels in the lakes. Both upstream and downstream interests became increasingly concerned about the flood control effects of headwaters lakes operation. Successive modifications of the operating regulations were made by which minimum levels were raised and storage capacity was drastically reduced.

Additional operating plan changes are continually proposed to the St. Paul District. For example, the Aitkin, Minnesota, area is interested in the operation of the headwaters lakes for whatever flood control benefits they might provide. The Twin Cities, Minnesota, area is interested in the headwaters lakes as a permanent or emergency water supply source. The Leech Lake Indians are interested in preserving the natural wild rice stands on Leech Lake which could be affected by any proposed change in lake operation. Power interests favor sustained high flows for optimum power production. Environmentalists are concerned with the overall effects of lake operation on natural resources.

GEOLOGY AND SOILS

The controlled headwaters lakes of the Mississippi River are located in north central Minnesota. The drainage basins of these lakes are located principally in Aitkin, Beltrami, Cass, Crow Wing, Hubbard, and Itasca Counties.

The upper three lakes - Winnibigoshish, Leech, and Pokegama - lie in a region of geologically young, gray, glacial drifts from the Keewatin Center which, in the Grand Rapids, Minnesota, area, become a thin veneer over a rugged moraine of Patrician or young red drift. Sandy, Pine River, and Gull Lakes lie in the red drift region. The gray drift is generally more clayey and less stony than the red drift. The drifts vary in thickness from 300 to 400 feet at the head of the Mississippi River to about 200 feet near Gull Lake.

Cass County which contains three of the controlled lakes (Winnibigoshish, Leech, and Gull) comprises 1,998 square miles of gently rolling upland surface and numerous lakes. This topography is the result of deposition of glacial drift during the Wisconsin Age. Three general types of deposition are found in Cass County. In the north, along the south shore of Lake Winnibigoshish, is a sandy outwash plain. South of this outwash, in the vicinity of Leech Lake, is a substantial zone of till plain. The southwestern portion of the county, from Leech Lake to northern Gull Lake, is part of the St. Croix moraine system.

At least 16 distinct types of soil are recorded in Cass County. The outwash of the northern part of the county has developed a very light-colored, loamy sand with low inherent agricultural fertility. The soils in the remainder of the county are mixtures of sand, clay, and loam of fair to good fertility. Organic peat soils occur in numerous low-lying areas throughout the county. These soils have good fertility potential but present problems in physical structure and water holding capability.

Aitkin County, in which Sandy Lake is located, is predominantly till plain with a large outwash area immediately to the northeast characterized by surface deposits of sand and gravel. The soil of the till plain area is brownish and slightly acidic, with pebbles and boulders of granite and gneiss.

Crow Wing County, in which Pine River Lake (12 lakes) is located, consists primarily of glacial outwash, with considerable moraine along the eastern border and till plain along the southern margin. Pine River Lake is located on outwash soils predominated by sand and clay with fair to poor fertility.

Itasca County, in which Pokegama Lake is located, is characterized by surface features resulting from the Wisconsin glaciation over 10,000 years ago. The soils are diverse. Loamy sands characterize the east central and west central portions of the county. Silty lake sediments occur in several townships. Erosion-prone sand and peat deposits of low fertility occur in the southeastern part of the county, and a belt of reddish clay loam extends from the southwest to the northeast.

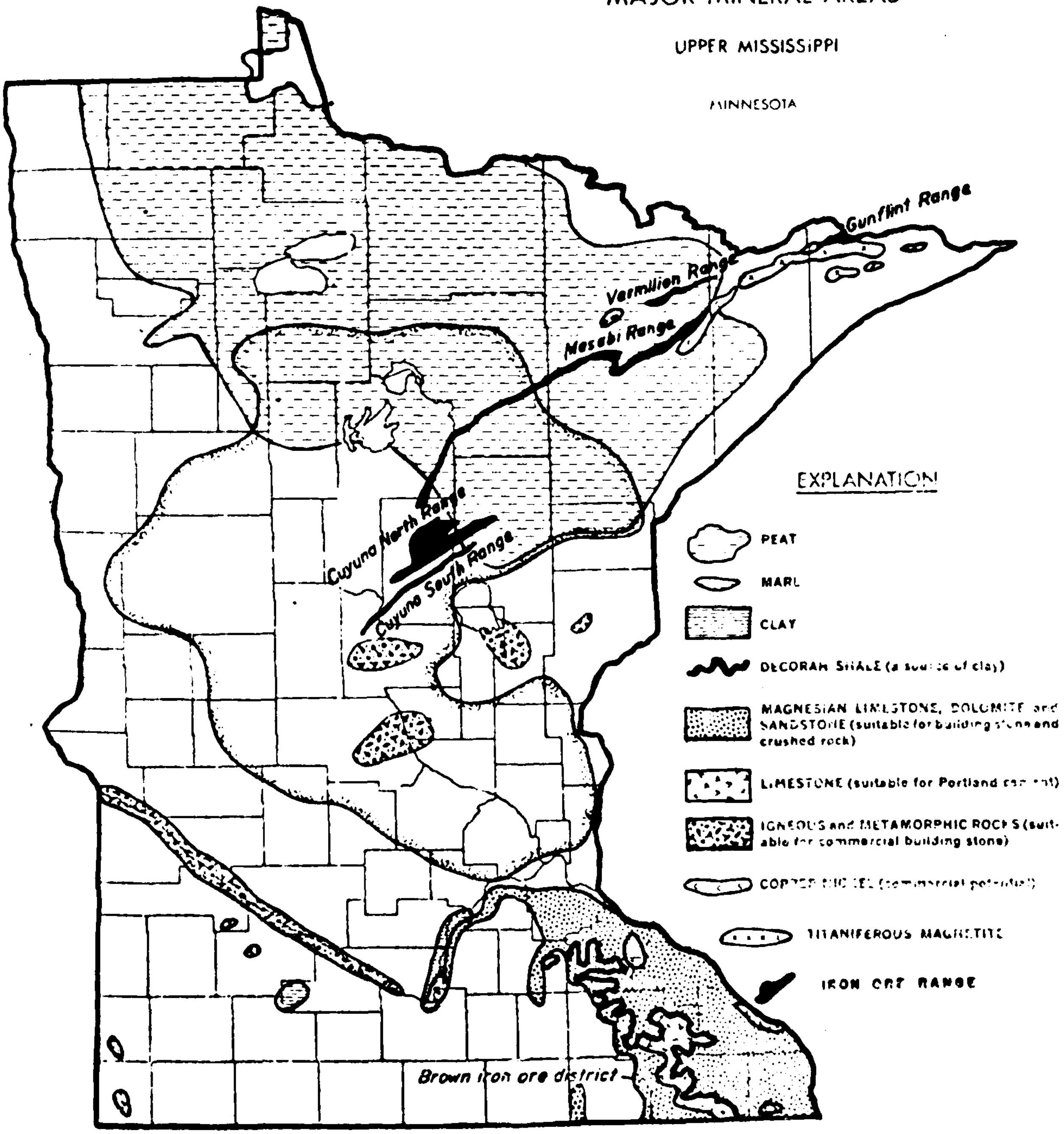
Veins of gravel and sand are located throughout the headwaters region, especially in the gray drift areas. These veins permit free interchange of water between the headwaters lakes and the underground water table. Sand and gravel deposits are found extensively in Cass, Crow Wing, and Itasca Counties as well as in and around Minneapolis-St. Paul, Minnesota, at the southern extreme of the study area.

The Mississippi River basin contains two iron ore ranges, the Mesabi and Cuyuna. In Itasca County, the Mesabi Iron Range extends northeast to southwest across the prairie and the Mississippi River, passing through and terminating several miles southwest of Grand Rapids. The Cuyuna Iron Range runs parallel to and south of the Mississippi River in Crow Wing County. The location of these two ranges with respect to the major mineral areas and surficial geology is shown on the following two figures.

MAJOR MINERAL AREAS

UPPER MISSISSIPPI

MINNESOTA

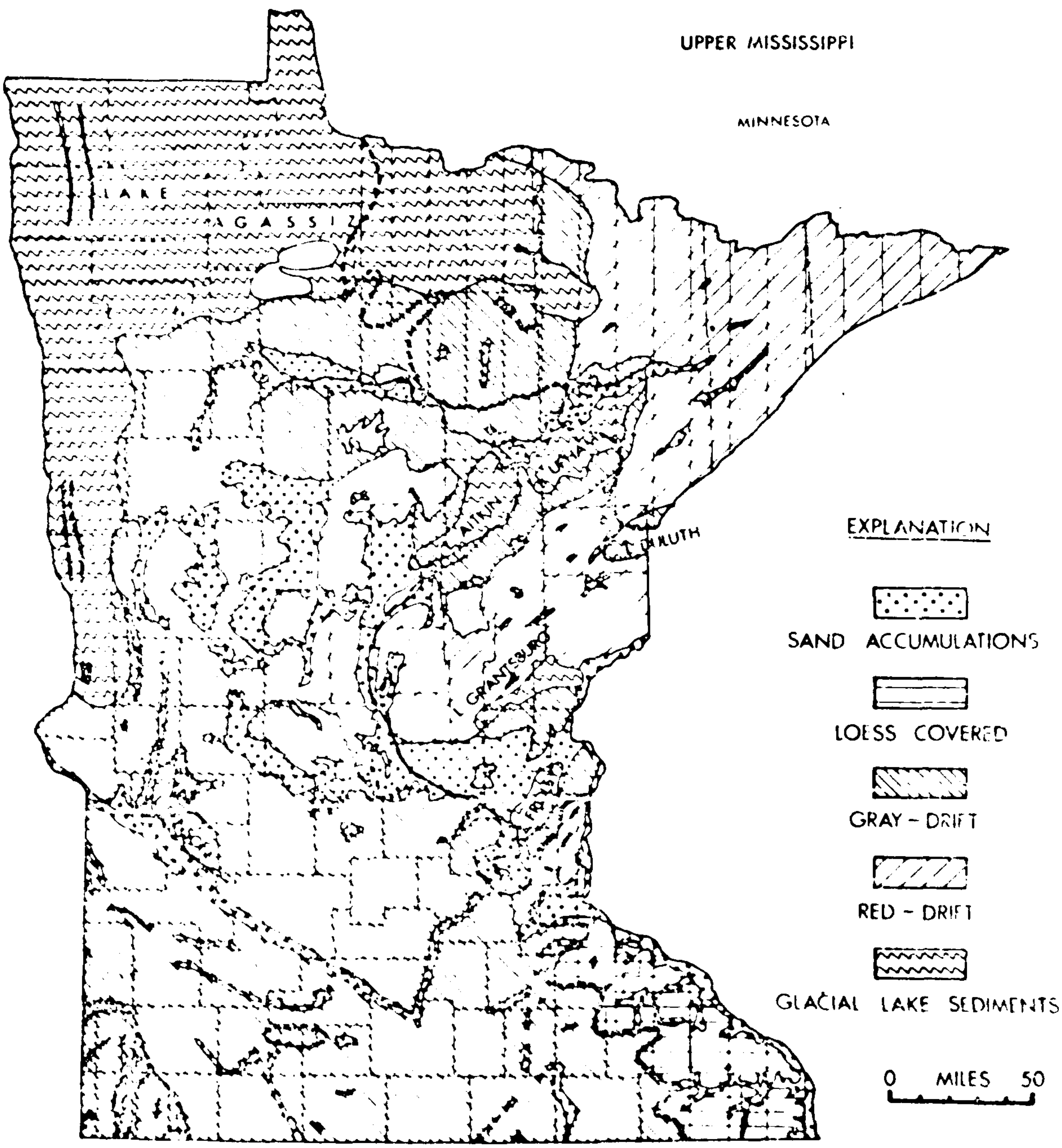


Source: Minnesota Geological Survey

SURFICIAL GEOLOGY

UPPER MISSISSIPPI

MINNESOTA



SOURCE: Minnesota Geological Survey

Iron ore reserves in the Mesabi range contain four major types: natural ore, nonmagnetic taconite, magnetic taconite, and semitaconite. The Cuyuna range has large reserves of nonmagnetic, low-grade ores.

No new subsurface investigations were conducted during this study. The geology and soils information developed for this report was already available from other sources.

STREAM CHARACTERISTICS

The Mississippi River varies from about 15 feet wide at the outlet of Lake Itasca to approximately 300 feet wide near Brainerd, Minnesota. In its uppermost reach, the river passes through several large lakes, three of which are Lake Bemidji (miles 1,304.0 to 1,301.3), Cass Lake (miles 1,283.7 to 1,276.1), and Winnibigoshish Lake (miles 1,263.8 to 1,247.9). Below Winnibigoshish Lake the Mississippi River joins the Leech Lake River at mile 1,223.8 and then winds through a low-lying area to Pokegama Lake at mile 1,183.8.

The Mississippi River in the vicinity of Days High Landing, Minnesota, has a slope of about 0.3 foot per mile and a channel flow capacity of about 2,000 cfs (cubic feet per second). The low-water profile of the Mississippi River between Grand Rapids and Brainerd is a fairly uniform slope of about 0.5 foot per mile between Grand Rapids and the mouth of the Rice River. It flattens to a slope of less than 0.2 foot per mile between the mouth of the Rice River and Pine Knoll and again assumes a slope of about 0.5 foot per mile below Pine Knoll. The decrease in slope between the mouth of the Rice River and Pine Knoll results from the numerous meanders which greatly increase the length of the channel in this reach. Channel widths between Grand Rapids and Brainerd vary from about 130 to 400 feet and channel flow capacities vary from about

5,000 cfs above the mouth of the Sandy River to approximately 12,000 cfs below Pine Knoll. In the vicinity of Aitkin, flows greater than 6,000 cfs exceed bank-full capacity. Drainage areas of the main stem and the principal tributaries and river mileages in the headwaters lakes area are given in the following table.

Drainage areas of the Mississippi River basin near the headwaters lakes

Stream	Miles above the mouth of the Ohio River (river mile)	Drainage area (square miles)	
		Tributary	Total Mississippi River (including tributary)
Mississippi River at Lake Itasca (outlet)	1,366.2	-	36
Mississippi River at Lake Bemidji (outlet)	1,301.3	-	596
Mississippi River at Winnibigoshish Dam	1,247.9	-	1,442
Leech Lake River (mouth)	1,223.8	1,246	2,780
Mississippi River at Days High Landing	1,203.8	-	3,175
Mississippi River at Pokegama Dam	1,183.8	-	3,265
Prairie River (mouth)	1,177.5	446	3,900
Swan River (mouth)	1,138.0	330	4,561
Sandy River (mouth)	1,105.6	423	5,060
Willow River (mouth)	1,077.5	483	5,579
Rice River (mouth)	1,065.7	356	5,965
Sisabagmah Creek (mouth)	1,057.8	45	6,030
Mud River (mouth)	1,056.9	106	6,140
Mississippi River (Aitkin)	1,055.9	-	6,140
Little Willow River (mouth)	1,048.8	87	6,240
Pine Knoll	1,040.1	-	-
Deer Brook (mouth)	1,036.1	23	6,300
Pine River (mouth)	1,023.8	802	7,130
Mississippi River at Brainerd	1,001.5	-	7,320

HYDROLOGIC AND HYDRAULIC STUDIES

General

A number of hydrology and hydraulic studies were conducted for the Mississippi River Headwaters Lakes in the years preceding 1976, when the present study was initiated. Most of the earlier studies dealt with flood operating plans that attempted to alleviate overall flood damages in the Upper Mississippi River basin by means of headwaters lakes operations. Much of the earlier work centered on the Aitkin and White Oak Lake areas, which are individually discussed in later sections of this report.

The most recent efforts involved:

a. A 1962-1966 Flow Determination Program Computer Study to evaluate the effects of lake operation on lakeshore property owners and downstream flooded interests and on possible low-flow augmentation for the metropolitan waste treatment plant located on the Mississippi River just downstream of St. Paul. This study ended inconclusively with no final report being prepared. Lack of study completion money, a shift in emphasis on other studies, and major flood problems within the St. Paul District prevented completion of the study. At cessation of study efforts, the current plan of operation for the six headwaters dams was considered reasonably satisfactory for most interests.

b. Work for the March 1972 interim survey report for a proposed dam at the outlet of White Oak Lake (Days High Landing Dam). This study report dealt primarily with the hydrologic effects on the Mississippi River in the vicinity of the proposed Days High Landing Dam (the area upstream from Pokegama Dam). A hydrologic study of the six headwaters lakes was conducted in 1978 and 1979, using the Hydrologic Engineering Center's HEC-5c computer program to evaluate the hydrologic and economic effects of four lake operating plans. The HEC-5c program evaluated these effects at six headwaters lakes and five downstream control points.

The current hydrologic study was conducted in 1981 and 1982. It involved a reevaluation of the hydrologic and economic effects of 10 operating plans using a new version of the HEC-5 computer program. Ultimately, only 8 of the 10 plans were evaluated by the model.

Basic Data

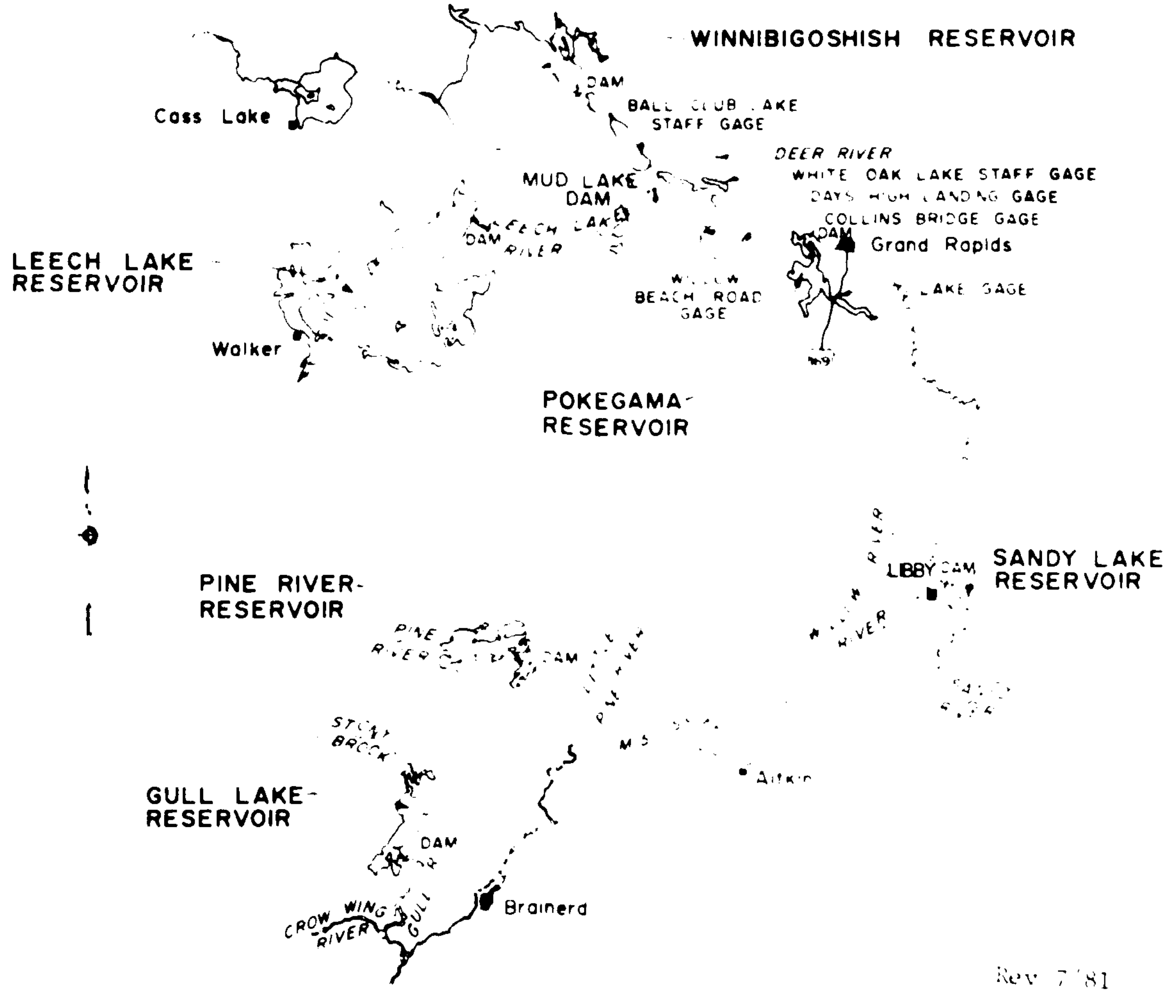
Much basic data exist for the Mississippi River Headwaters area, and it is difficult to select from the vast array of material. For this study, an attempt was made to include backup material that would be useful in evaluating the study procedure and results. Several items basic to any reservoir study are individual site plans (plates A-2 through A-7), surface area curves (plate A-8), and elevation-storage curves (plates A-9 through A-14).

Much of the early data for the Mississippi River Headwaters area was related to United States Engineer Survey Datum (USED). The USED survey datum was used in the survey and construction of the Mississippi River Headwaters dams. Stages were also used at each damsite for a convenient reference. Stages were elevations in feet above a convenient reference point such as the stream bottom, average low water, or structure apron. There was no established relationship between stages at each of the six headwaters lakes dams, except the USED survey elevations.

Additional survey elevations above mean sea level were later introduced in the headwaters area with nationwide survey datums (1912 and 1929 adjustment). The three survey datums and stage data led to much confusion, and in 1973 a decision was made to reference all headwaters elevation data to the 1929 adjustment survey datum. Therefore, for this report, all data will be referred to the 1929 adjustment survey datum or a combination of stage and 1929 adjustment survey datum, where deemed helpful. Many local people in the headwaters area prefer and continue to use the stage reference; thus, use of both references was considered essential in some areas of this report.

The following two tables compare the elevations and stage datums previously in use with pertinent operating limits, storages, and other features.

GENERAL OPERATING DATA - MISSISSIPPI RIVER HEADWATERS RESERVOIRS



LAKE ELEVATIONS IN FEET - 1929 ADJ.						
RESERVOIR	WINNI-BIGOSHISH	LEECH	POKEGAMA	SANDY	PINE	GULL
NORMAL SPRING STAGE (DATE)	1296 94(3/1)	1293 20(3/1)	1270 42(3/15)	1214 31(2/15)	1227 32(2/15)	1192 75(2/15)
DESIRABLE SUMMER RANGE	1298 94-1299 44	1294 50-1294 90	1273 17-1273 67	1216 06-1216 56	1229 07-1229 57	1193 75-1194 00
ORIGINAL OPERATING LIMITS	1288 94-1303 14	1292 20-1297 94	1268 92-276.42	1207 91-1218 31	1217 62-1234 82	1188 75-1194 75
CAPACITY, ORIGINAL OPERATING LIMITS, AC-FT	967,900	743,300	120,800	78,700	178,900	70,800
PRESENT OPERATING LIMITS	1294 94-1303 14	1292 70-1297 94	1270 42-1276 42	1214 31-1218 31	1225 32-1231.32	1192 75-1194 75
PRESENT ORDINARY OPERATING LIMITS	1296 94-1300 94	1293 20-1295 70	1270 42-1274 42	1214 31-1218 31	1226 32-1230 32	1192 75-1194 75
DESIRABLE OPERATING LIMITS	1296 94-1299 44	1293 20-1295 70	1271 42-1274 42	1214 31-1218 31	1227 32-1230 32	1192 75-1194 75
CAPACITY, PRESENT OPERATING LIMITS, AC-FT	653,600	689,800	102,400	37,600	79,900	26,000
FLOWAGE RIGHTS ACQUIRED TO ELEVATION OF	1306 94+	1301 70+	1280 42+	1222 31+	1238 82+	1198 75+
MAXIMUM ELEVATION EVER ATTAINED	1303 39	1297 88	1277 92	1224 82	1234 56	1195 05
NUMBER OF TIMES UPPER OPERATING LIMIT HAS BEEN EXCEEDED	2	0	18	18	0	8
NO TIMES FLOWAGE LIMITS HAVE BEEN EXCEEDED	0	0	0	1	0	0
MAXIMUM ELEVATION ATTAINED 1950	1303 17	1296 81	1277 39	1224 82	1231 41	1195 01
RESERVOIR IN OPERATION	1884	1884	1884	1895	1886	1912

STAGES IN USE PRIOR TO JULY 1973						
RESERVOIR	WINNI-BIGOSHISH	LEECH	POKEGAMA	SANDY	PINE	GULL
NORMAL SPRING STAGE (DATE)	8.0 (3 1)	0.5 (3 1)	6.0 (3 15)	7.0 (2 15)	11.0 (2 15)	5.0 (2 15)
DESIRABLE SUMMER RANGE	10.0-10.5	1 8-2 2	8.75-9.25	8.75-9.25	12.75-13.25	6.0-6.25
ORIGINAL OPERATING LIMITS	0'-14.2'	-0.5'-5.24'	4.5'-12'	0 6'-11	1 3'-18 5'	1 0' 7 0'
CAPACITY, ORIGINAL OPERATING LIMITS AC FT	967,900	743,300	120,800	78,700	178,900	70,800
PRESENT OPERATING LIMITS	6'-14.2'	0'-5.24'	6'-12'	7'-11'	9 15.0	5' 7'
PRESENT ORDINARY OPERATING LIMITS	8'-12'	0.5'-3.0'	6'-10'	7'-11'	10' 14'	5' 7'
DESIRABLE OPERATING LIMITS	8'-10.5'	0.5'-3 0'	7'-10'	7'-11'	11'-14'	5' 7'
CAPACITY, PRESENT OPERATING LIMITS AC-FT	653,600	689,800	102,400	37,600	79,900	26,000
FLOWAGE RIGHTS ACQUIRED TO STAGE OF	18'-	9'-	16'-	15'-	22 5'-	11 0 -
MAXIMUM STAGE EVER ATTAINED	14 45'	5 18'	13.50'	17 51'	18 24'	7 3'
NUMBER OF TIMES UPPER OPERATING LIMIT HAS BEEN EXCEEDED	2	0	18	18	0	8
NO TIMES FLOWAGE LIMITS HAVE BEEN EXCEEDED	0	0	0	1	0	0
MAXIMUM STAGE ATTAINED IN 1950	14 23'	4 11'	12 97'	17 51'	15 09'	7 26'
ZERO OF GAGE:						
(U S E ' DATUM)	1290 08'	1293 76'	1265 27'	1209 00'	1218 20'	1190 00'
(M S L 1912 ADJ)	1289 47'	1293 23'	1264 89'	1207 70'	— — —	1188 14'
(M S L 1929 ADJ)	1288 94'	1292 70'	1264 42'	1207 31'	1216 32'	1187 75'
RESERVOIR IN OPERATION	1884	1884	1884	1895	1886	1912

TOP OF PIERS	15.42	6.84	14.0	14.0	19.5	10.0
SILL	-4.78	-4.96	0.00	0.00	+0.33	+1.0

The following two tables provide an overview of information on the six headwaters lakes control structures.

Mississippi River Headwaters Lakes - general dam data[1]

Item	Winnibigoshish	Leech	Pokegama	Sandy	Pine River	Gull
Dam						
Type	Earth fill with timber diaphragm core filled with puddled clay					Concrete curtain wall, earth fill
Crest stage height	22.42	10.54±	14.00	14.00[2]	22.5	10.0
Length (feet)	1,000	3,300	160	105[2]	1,265	201
Maximum height (feet)	29	15.0±	15.0	14.0[2]	24.1	10.5
Freeboard above maximum stage (feet)	8	5.4±	0.5	0.5-3.0	4.0	3.5
Control structure						
Type	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
Sill stage height	-4.78	-4.96	0.00	0.00	+0.33	+1.00
Net length of spillway crest (feet)	87	162	116	66	78	36
Stage height of piers	15.42	6.84	14.00	14.00	19.5	10.0
Sluiceways						
Number of bays	6	26	14	12	13	7
Number of stop log sections	16	26	14	7	13	6
Stage height of stop logs at full pool	14.2	5.24	12.00	11.0	18.5	7.0
Log sluice width (feet)	12	12	12	11	6	11
Fishway width (feet)	5 (not used)	None	None	None	None	5 (in use)
Discharge channel capacity (square feet)	2,000	1,500 (est)	6,000[3]	1,500[4]	2,500	1,100
Spillway apron						
Type	Timber	Concrete	Concrete	Concrete	Concrete and timber	Concrete
Length (feet)	148.5	39	52	41	86	73
Width (feet)	138.5	294	225	68	150	68 feet 11 inches
Floor stage height	-6.58	-4.96	0.00	0.00	+0.33	+1.00
Bridge over control structure						
Road	Public road	Public road	None	Road closed to public		Public road
Floor stage height	22.42	10.09	-	16.2	20.5±	10.5
Roadway width (feet)	20	8 feet 10 inches	-	8	8	8
Stage height of walkway	23.42	10.84±	14.00	14.0	None	10.0
Elevation of gage zero (1929 adjustment)	1283.94	1292.70	1264.42	1207.31	1216.32	1187.75

(1) All heights in this table are above or below the zero of the gages.

(2) After the 1950 flood the dam and access road were raised. The right bank portion was raised to 18.0 feet. The left bank portion and access road were raised to 20.5 feet. Total length of the raised section is 1,586 feet.

(3) Flooding of Blackberry area pasture lowlands starts at approximately 3,500 cfs.

(4) Affected by Mississippi River backwater.

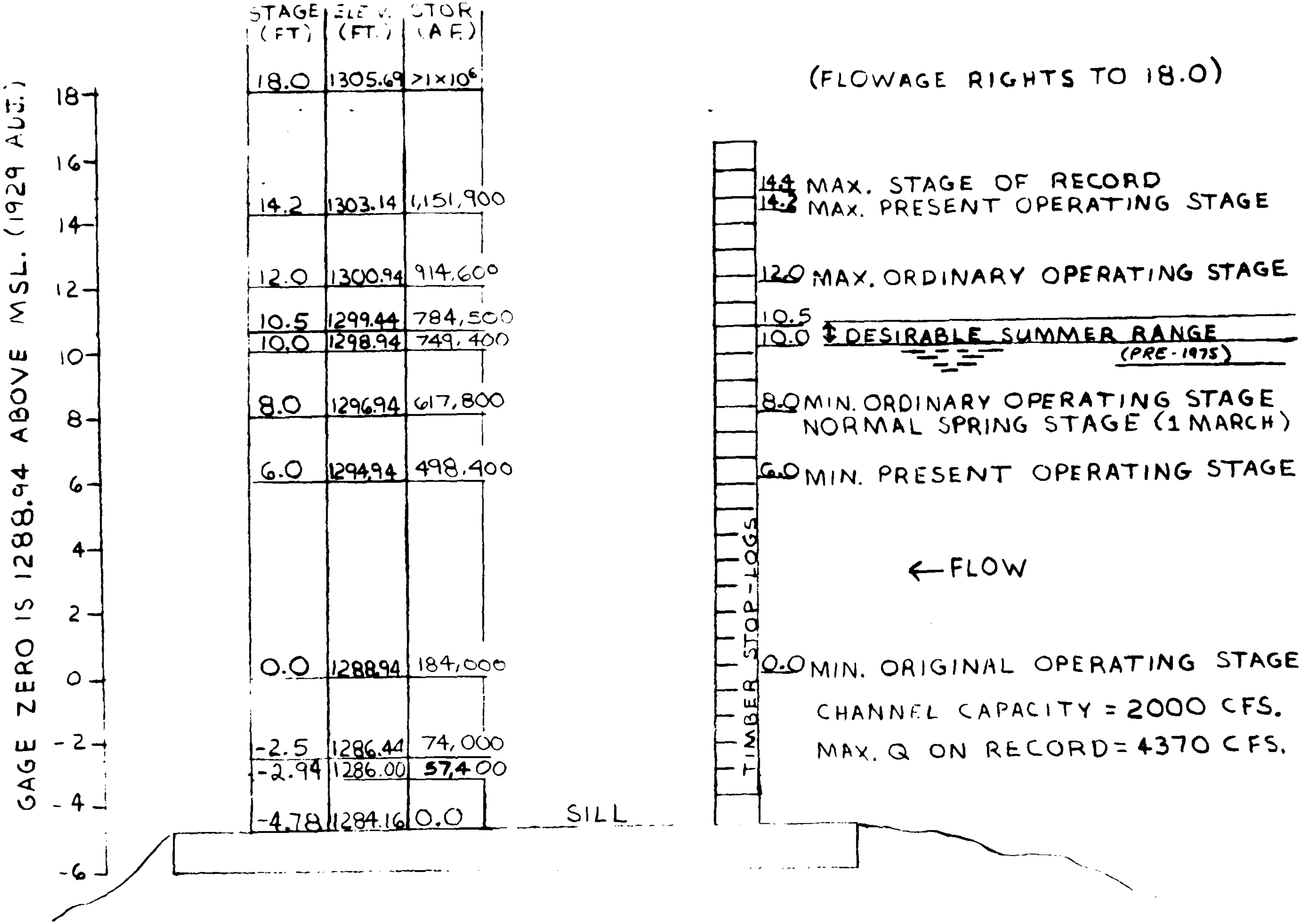
Mississippi River Headwaters Lakes - maximum data

Lake	Maximum[1] operating stage	At maximum operating stage: Maximum discharge (cfs)	At maximum operating stage: To prevent flooding downstream-maximum discharge (cfs)	Maximum stages of record	Year	Discharge (cfs)	1950 maximums: Stage	1950 maximums: Discharge (cfs)
Winnibigoshish	14.20	4,000	2,000[2]	14.45	1905	4,369	14.23	2,670
Leech	5.24	5,000	1,500[2]	5.20	1916	1,675	4.05	12-1,300
Pokegama	12.00	4,000	3,500	12.88	1905	5,250		
				13.47	1948	4,515	12.97	3,500
Sandy	11.00	1,500	1,500	15.05	1897	3,738	17.50	3,500
Pine	18.50	2,500	2,500	15.34	1896	2,246		
				18.24	1916	589	14.80	1,600
Gull	7.00	1,100	1,100	7.21	1938	1,123	7.30	1,100

(1) Reference gage zeros in msl (1929 adjustment) on previous table.
(2) Normally the combined releases from Winnibigoshish and Leech Lakes are maintained at 2,500 cfs maximum to prevent minor downstream flooding between these two lakes and Pokegama Dam.

The following six figures are graphical profiles of each of the six headwaters lakes showing relationships between stage, elevation, storage, and operating limits. The stage in feet at each lake control structure was referenced to the structure flow level or gate sill which was at zero elevation. Area and capacity data shown on these figures and on plates A-9 to A-14 are derived from the 1945 surface area curves shown on plate A-8.

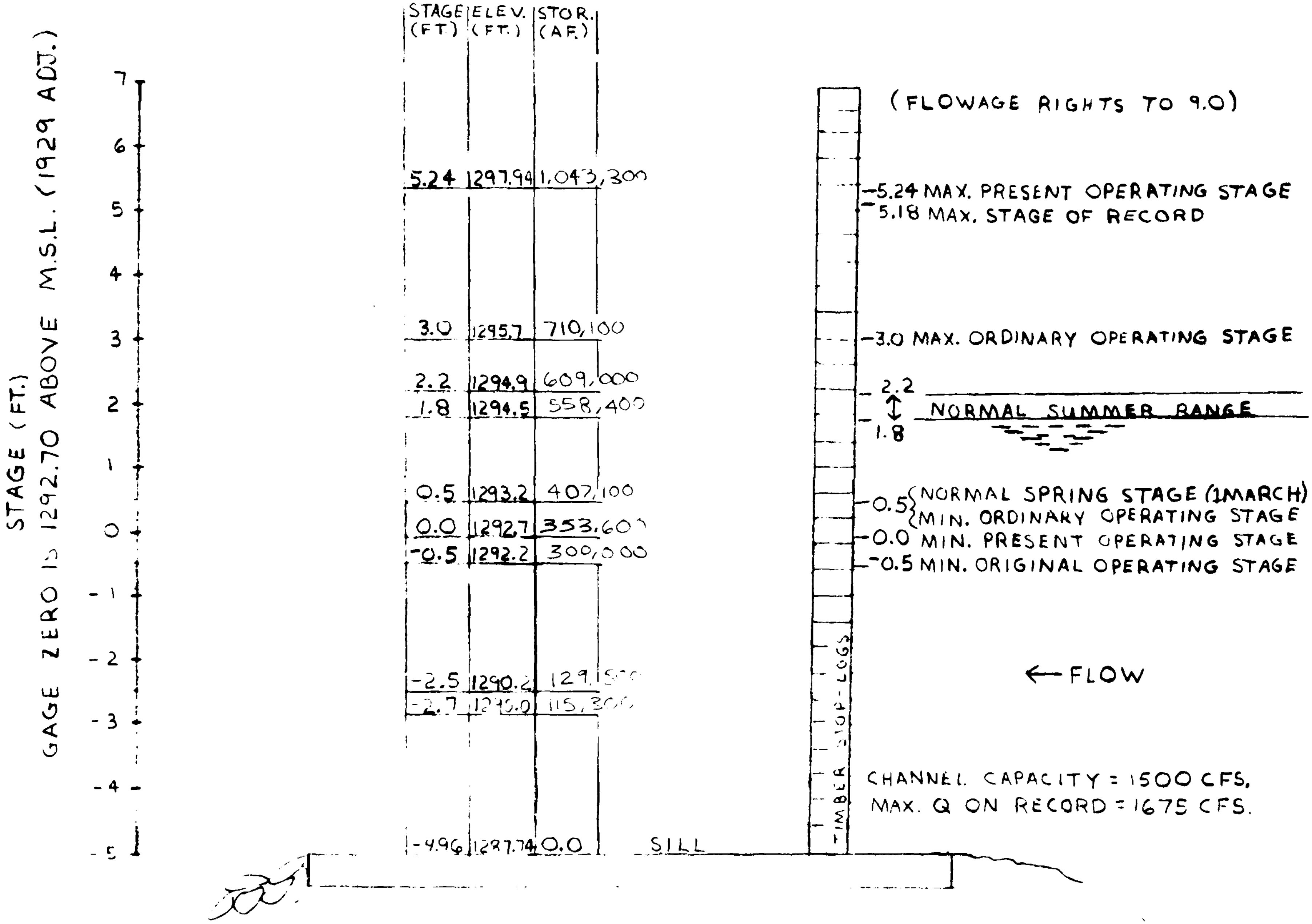
WINNIBIGOSHISH LAKE DETAILS



STAGE (FT)	ELEV. (FT.)	STOR (A.F.)
18.0	1305.69	>1×10⁶
14.2	1303.14	1,151,900
12.0	1300.94	914,600
10.5	1299.44	784,500
10.0	1298.94	749,400
8.0	1296.94	617,800
6.0	1294.94	498,400
0.0	1288.94	184,000
-2.5	1286.44	74,000
-2.94	1286.00	57,400
-4.78	1284.16	0.0

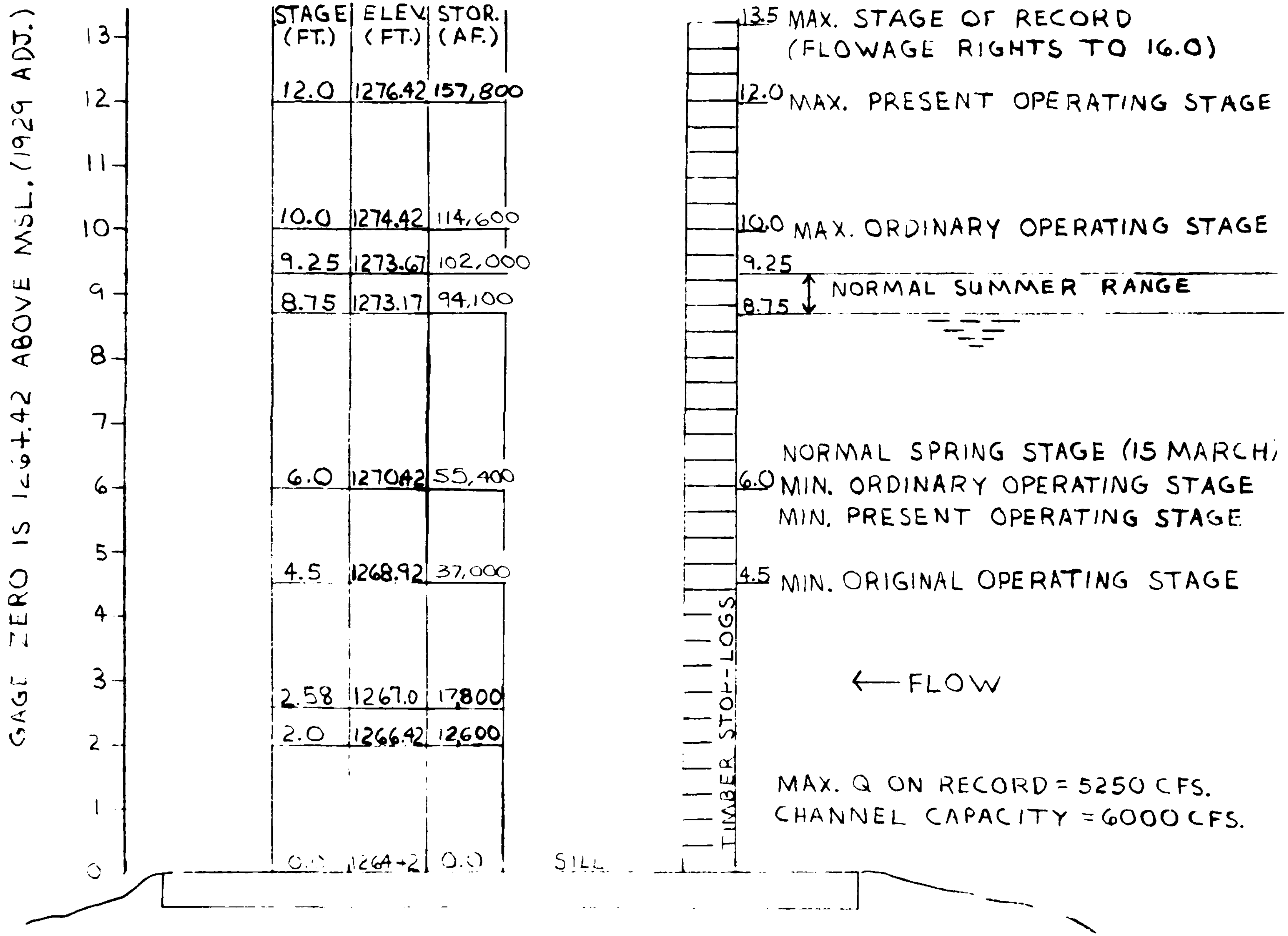
LEECH LAKE DETAILS

STAGE (FT.)	ELEV. (FT.)	STOR. (A.F.)
5.24	1297.94	1,043,300
3.0	1295.7	710,100
2.2	1294.9	609,000
1.8	1294.5	558,400
0.5	1293.2	407,100
0.0	1292.7	353,600
-0.5	1292.2	300,000
-2.5	1290.2	129,500
-2.7	1290.0	115,300
-4.96	1287.74	0.0



POKEGAMA LAKE DETAILS

STAGE (FT.)	ELEV. (FT.)	STOR. (AF.)
12.0	1276.42	157,800
10.0	1274.42	114,600
9.25	1273.67	102,000
8.75	1273.17	94,100
6.0	1270.42	55,400
4.5	1268.92	37,000
2.58	1267.0	17,800
2.0	1266.42	12,600
0.0	1264.42	0.0

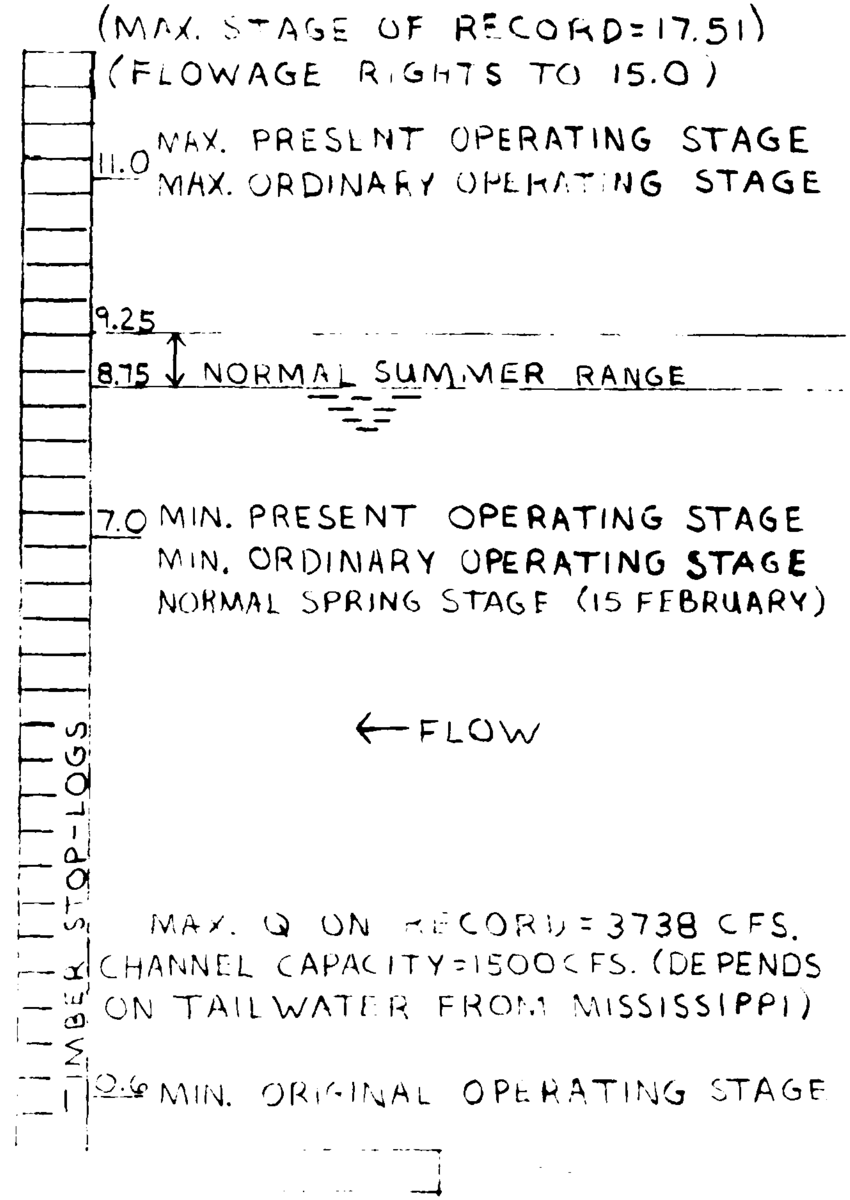


SANDY LAKE DETAILS

STAGE (FT)

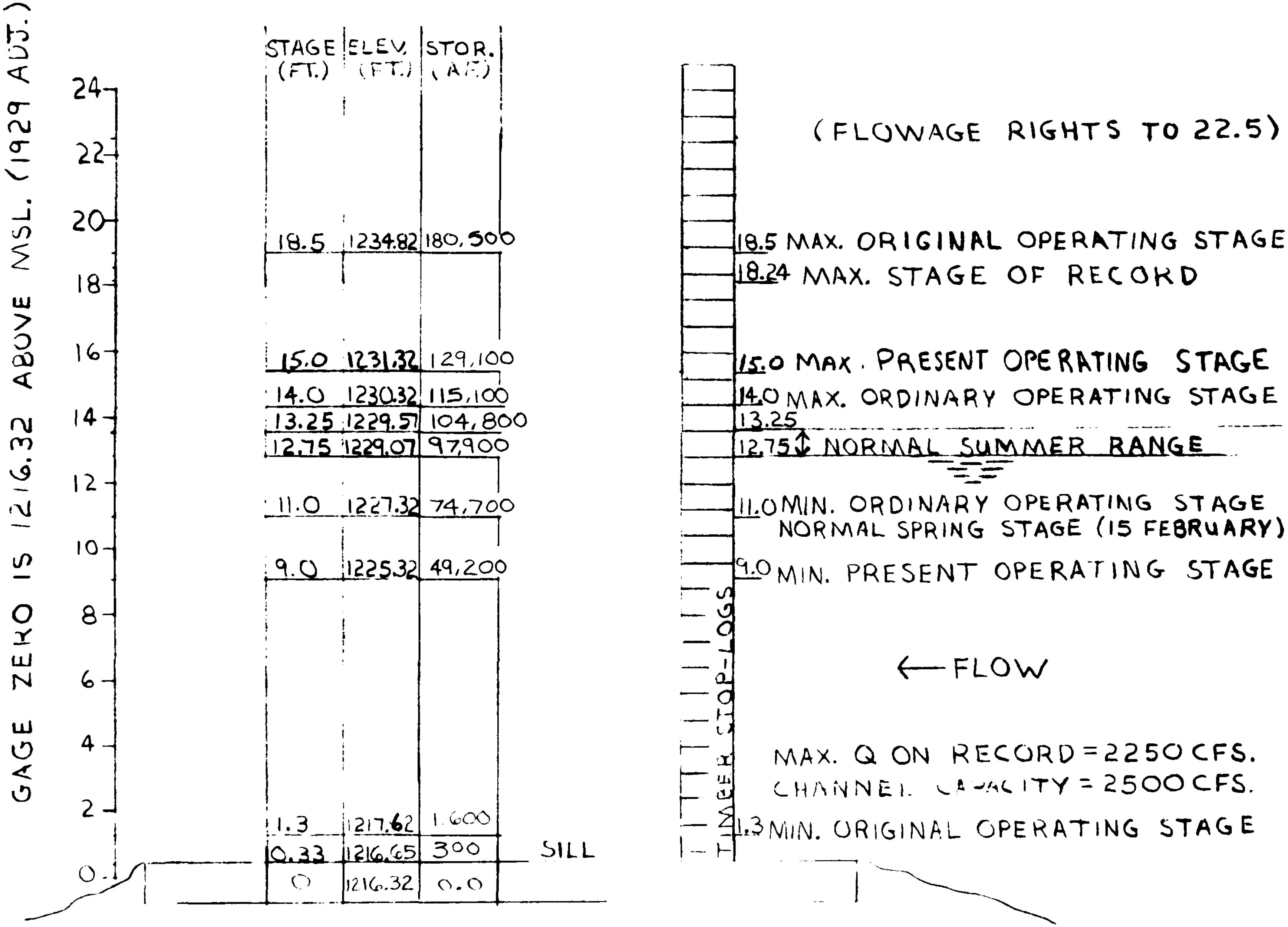
GAGE ZERO IS 1207.31 ABOVE MSL. (1929 ADJ.)

STAGE (FT)	ELEV. (FT)	STOR. (AF)
11.0	1218.31	81,900
9.25	1216.56	64,300
8.75	1216.06	59,600
7.0	1214.31	44,400
0.6	1207.91	[illegible]
0.0	1207.31	0

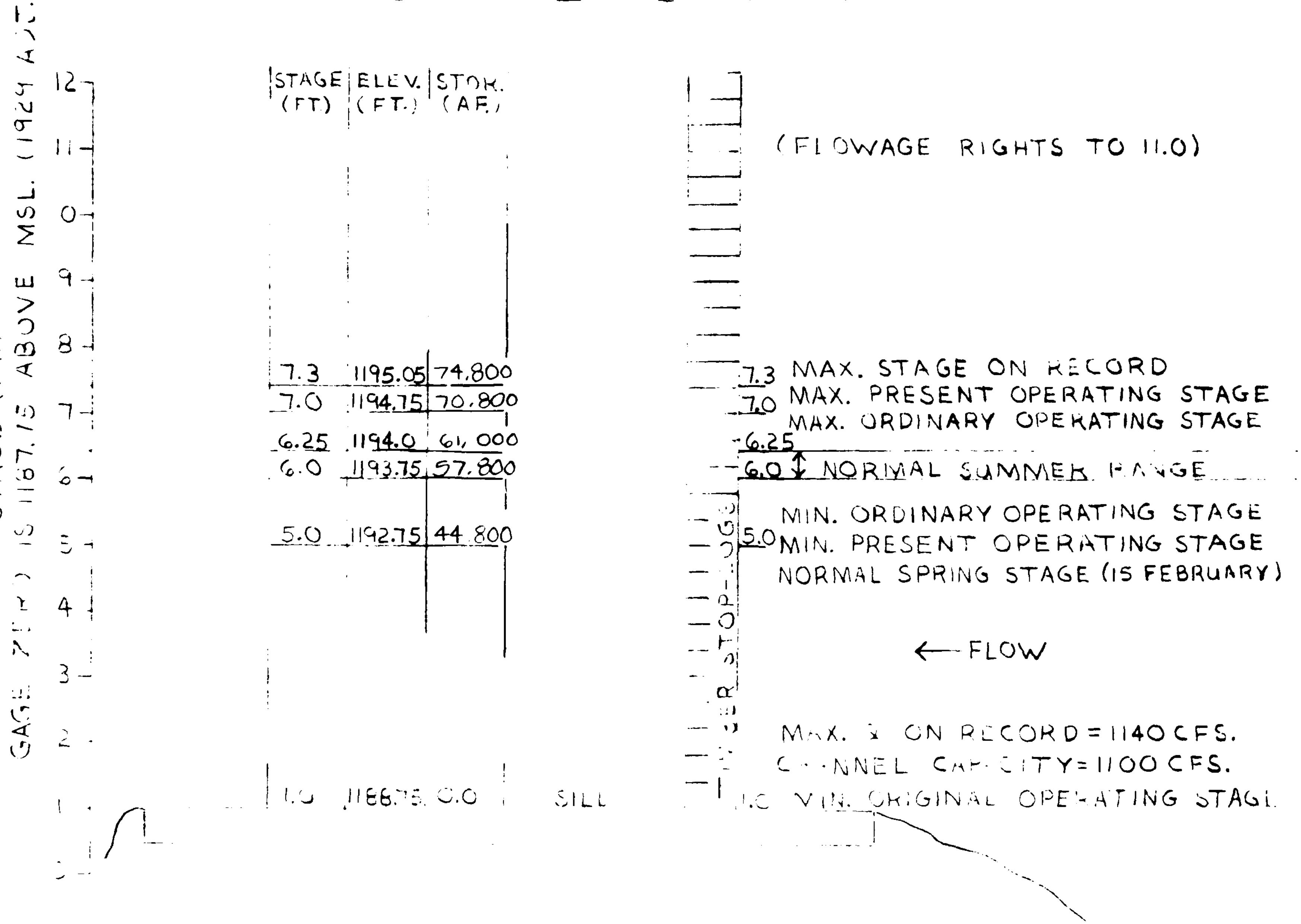


PINE RIVER LAKE DETAILS

STAGE (FT.)	ELEV. (FT.)	STOR. (A.F.)
18.5	1234.82	180,500
15.0	1231.32	129,100
14.0	1230.32	115,100
13.25	1229.57	104,800
12.75	1229.07	97,900
11.0	1227.32	74,700
9.0	1225.32	49,200
1.3	1217.62	1,600
0.33	1216.65	300
0	1216.32	0.0



GULL LAKE DETAILS



The earliest attempts to accurately define the acreages and capacities of the six headwater lakes occurred in 1925 and again in 1931. Areas and capacities were tabulated at those times from planimetered flowage maps. The lake surface areas were later shown on the July 1945 Mississippi River Headwaters Area Curve drawing. These area curves were also used to develop the lake storages or capacities used in the April 1963 Master Reservoir Regulation Manual used by the Reservoir Regulating Section.

In the capacity evaluation, no attempt was made to define the total storage in each natural lake, but only the amount of active storage above some arbitrary zero elevation. Lake bottom elevations were not sufficiently defined for this purpose, nor was there the need, from an operation standpoint, to quantify the available "dead storage." Unfortunately, the earlier "zero" storage designations were based on arbitrary assignments related to normal lower operating limits. Observed lake levels sometimes exceeded the "zero" lower limit, resulting in negative storage values. For the purpose of this study (as shown on plates A-9 to A-14) the zero-storage levels were assigned to the structures sill elevations or close to them. This eliminated negative storage values. As a result, the storages referred to in this report may differ from those in other sources such as the 1963 Master Reservoir Regulation Manual. In general though, the incremental storage values for other data sources are the same.

STAGE 2 STUDIES

General

Several operating plans for the six Mississippi River Headwaters Lakes were initially evaluated using Generalized Computer Program HEC-5c. The program was used to evaluate the effects of varying the lake operating plans on downstream areas such as Aitkin and the Twin Cities. The analysis was summarized in the draft stage 2 report on the Mississippi River Headwaters Lakes study, September 1979.

The HEC-5c computer program used 11 control points, which included the 6 headwaters lakes dam locations and 5 downstream locations (Libby, Aitkin, Royalton, Anoka, and St. Paul, Minnesota, U.S. Geological Survey gage locations). The control point locations are shown on plate A-1.

Plans Evaluated

Four plans were evaluated with the HEC-5c program early in the stage 2 study and included:

- Natural conditions.
- Present conditions.
- Low-flow plan for the Twin Cities emergency water supply.
- Flood control for Aitkin.

A brief discussion of each of these four plans follows.

Plan 1: Present Operating Plan

The present plan of operation is reasonably successful in satisfying the diverse but related interests in stable water levels. These interests include lake docking facilities and wild rice production upstream and downstream of the dams, water supply, fish and wildlife conservation, hydropower and power plant cooling water needs, flood control, and navigation.

Basically, the six lakes are operated to provide optimum levels for recreation and fish and wildlife interests except during floods. During flood periods, Winnibigoshish and Leech Lakes, the two largest lakes, are operated to provide available storage early in the spring so that outflows can be reduced to near zero during high stages at Aitkin. The two lakes farther downstream, Pokegama and Sandy Lakes, are regulated in parallel with the observed stages at Aitkin to cause the least total damage in the Pokegama, Sandy, and Aitkin areas. Pine River and Gull Lakes are operated exclusively to prevent flooding of lake property owners during these times.

The present plan of operation is the product of continual refinement and adjustments to broad operating limits for each of the lakes. The plan has been developing since the headwaters dams were constructed in the late 1800's and early 1900's. Cumulative refinements and adjustments have been made as a result of public hearings and studies carried out since that time.

The tentative guide curves for Pokegama-Sandy-Aitkin are shown on plates A-15 and A-16 and the Aitkin rating curve is shown on plate A-17.

Plan 2: Water Supply Plan for the Twin Cities

The present plan of operation of the headwaters lakes does not provide for separate or special flow releases for Twin Cities municipal or industrial water uses. The proposed plan would allow additional flow releases to insure that flows entering the Twin Cities metropolitan area (at Anoka) would not drop below approximately 1,600 cfs. This flow is considered to be the minimum required to meet water supply and steam power needs in the Twin Cities area in the year 2015. This flow would also meet navigation and irrigation requirements upstream of Anoka. The following table summarizes the derivation of minimum Upper Mississippi River flow requirements (including the Twin Cities).

Preliminary summary of Upper Mississippi River low-flow water needs, including the Twin Cities

Use	Need (million gallons per day)				
	1970	1980	1990	2000	2015
Navigation[1]	225	225	225	225	225
Irrigation upstream of Anoka[2]	20	47	67	87	120
Hydropower and steam electric demands[3]	437	437	437	437	437
Twin Cities area water supply					
Total[4]	306.1	381.2	509.1	679.2	1,010[6]
Surface water only[5]	101.1	151.2	189.1	256.2	485[6]
Amount required to meet surface water needs (irrigation, hydropower, and Twin Cities surface water supply)	558.1 (865 cfs)	635.2 (985 cfs)	693.1 (1,075 cfs)	780.2 (1,210 cfs)	1,042 (1,615 cfs)

(1) Minneapolis-St. Paul Level B Study, June 1977, page IX-3.
(2) 9 September 1964 summary of water quality and irrigation needs by the Corps of Engineers.
(3) Based on peak cooling demand at Riverside steam power plant (from Level B, Minneapolis-St. Paul Water Supply Task Group Technical Paper).
(4) Minneapolis-St. Paul Level B Study, June 1977, Page V-5.
(5) From figure 1 (same source as footnote 3).
(6) Extrapolation.

Plan 3: Flood Control Plan for Aitkin

This plan evaluates the economic effects of assuming the lakes are to be operated exclusively for flood control at Aitkin without regard for damage to lake property. In contrast, the present approach to providing flood protection for the Aitkin area by controlling outflow from the four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy) is limited primarily by established minimum drawdown levels in the lakes, maximum water levels that can be tolerated by lake property owners, hydraulic limitations of channel capacities, and the outflow capacities of the control dams. Plan 3 would not attempt to minimize flood damages in the headwaters area but would attempt to protect the Aitkin area at all costs.

Plan 4: Natural Conditions

This plan considers the hydrologic results of returning to natural conditions; that is, the conditions with no dams controlling elevations or flows from the six headwaters lakes. This alternative provides a useful comparison for those who might be critical of present operation and think that natural conditions would be better. A natural condition analysis is essential to compare the effects that an operating plan has had on natural lake levels and flows.

Damages

High- and low-water damages were developed for each of the six headwaters lakes. High-water damages were developed for the downstream Aitkin area, and low-water damages were developed for the Anoka area even farther downstream. The methodology used in the analysis is described later in the stage 3 discussion as the methods were the same. The stage 2 damages were used with the HEC-5c program output to arrive at a comparison of average annual damages for each plan evaluated as described in the "Conclusions" section.

Initial Results

The following products resulted from the study and were included in an August 1979 contractor's report by the University of Minnesota's St. Anthony Falls Hydraulic Laboratory(SAFHL).

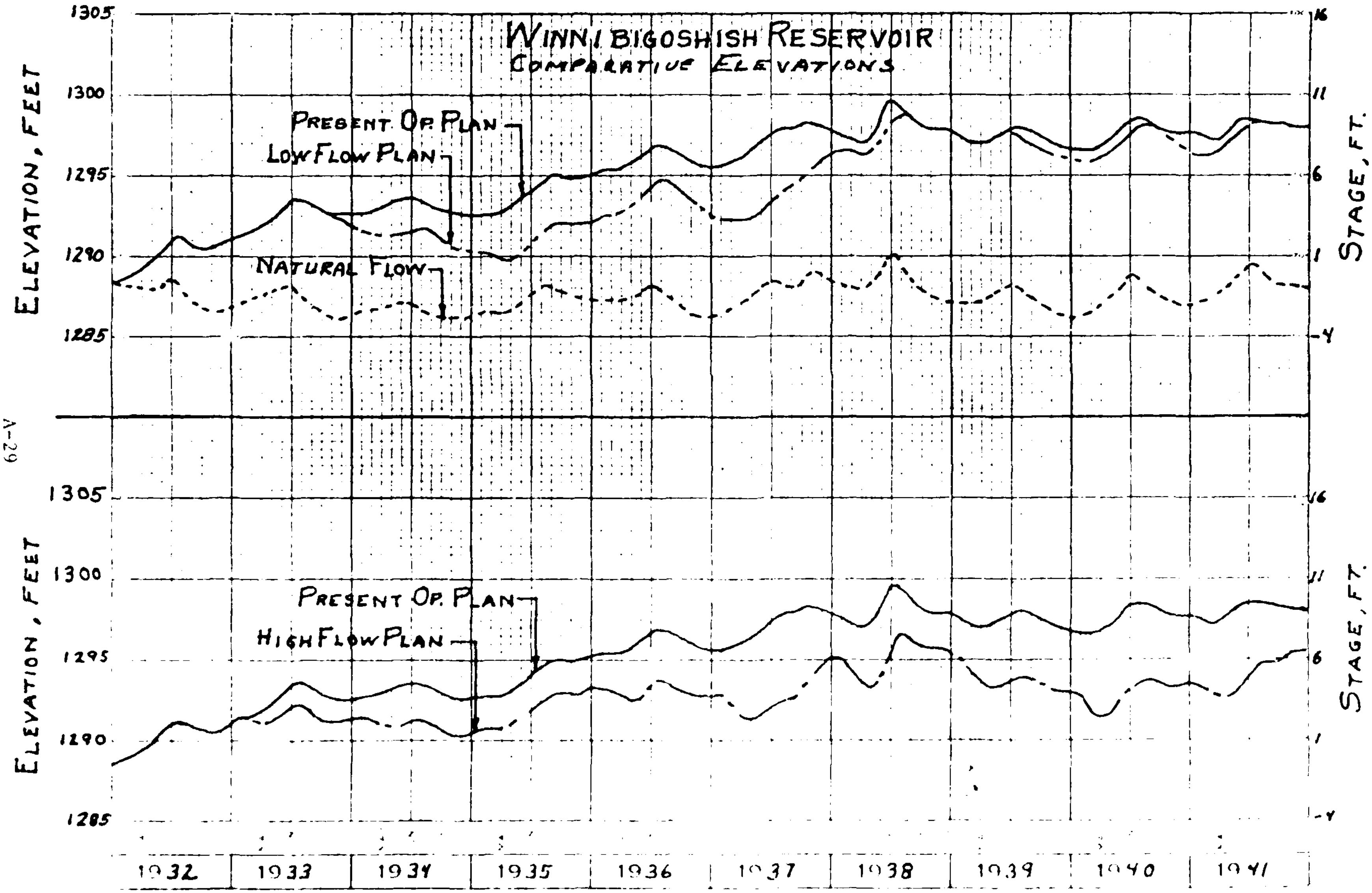
a. Plots of both low and high stage-frequency curves for each of the six headwaters lakes for the period 1932 to 1976 for each of the operating plans investigated. The curves were developed for the recreation season 1 May to 30 September.

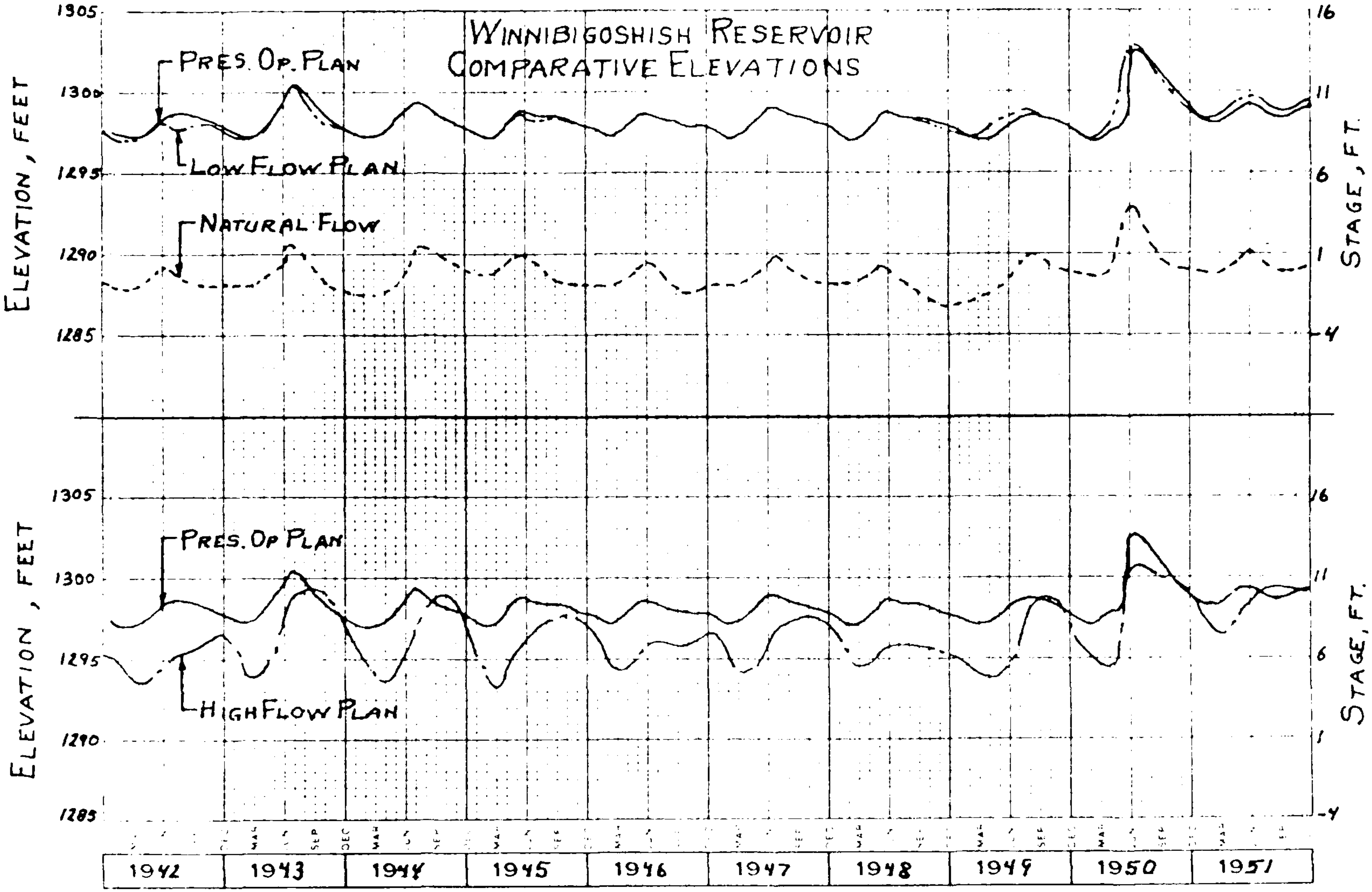
b. Plots of high-flow frequency curves at Aitkin and plots of low-flow frequency curves at the Anoka gage for the period 1932-1976 for each of the plans investigated. The curves were developed for the recreation season 1 May to 30 September.

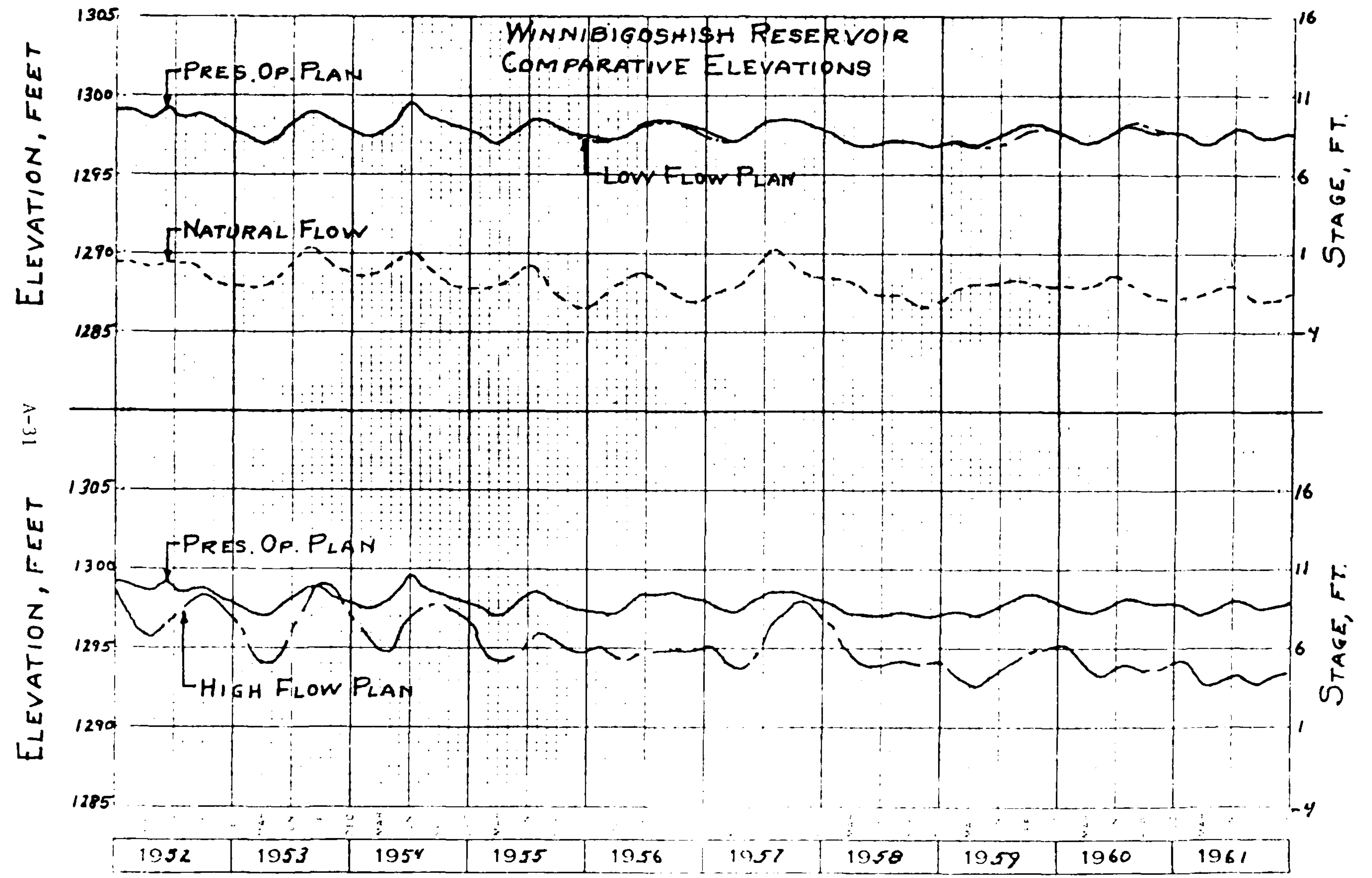
c. Plots of four operating plan effects at the Anoka gage and at each of the six headwaters lakes for the period 1932 to 1976. (Damages and benefits were developed at 6 5/8-percent interest and October 1977 price levels.)

d. Summary of average annual damages at each of the six headwaters lakes, at Aitkin, and at the Anoka gage for the operating plans evaluated.

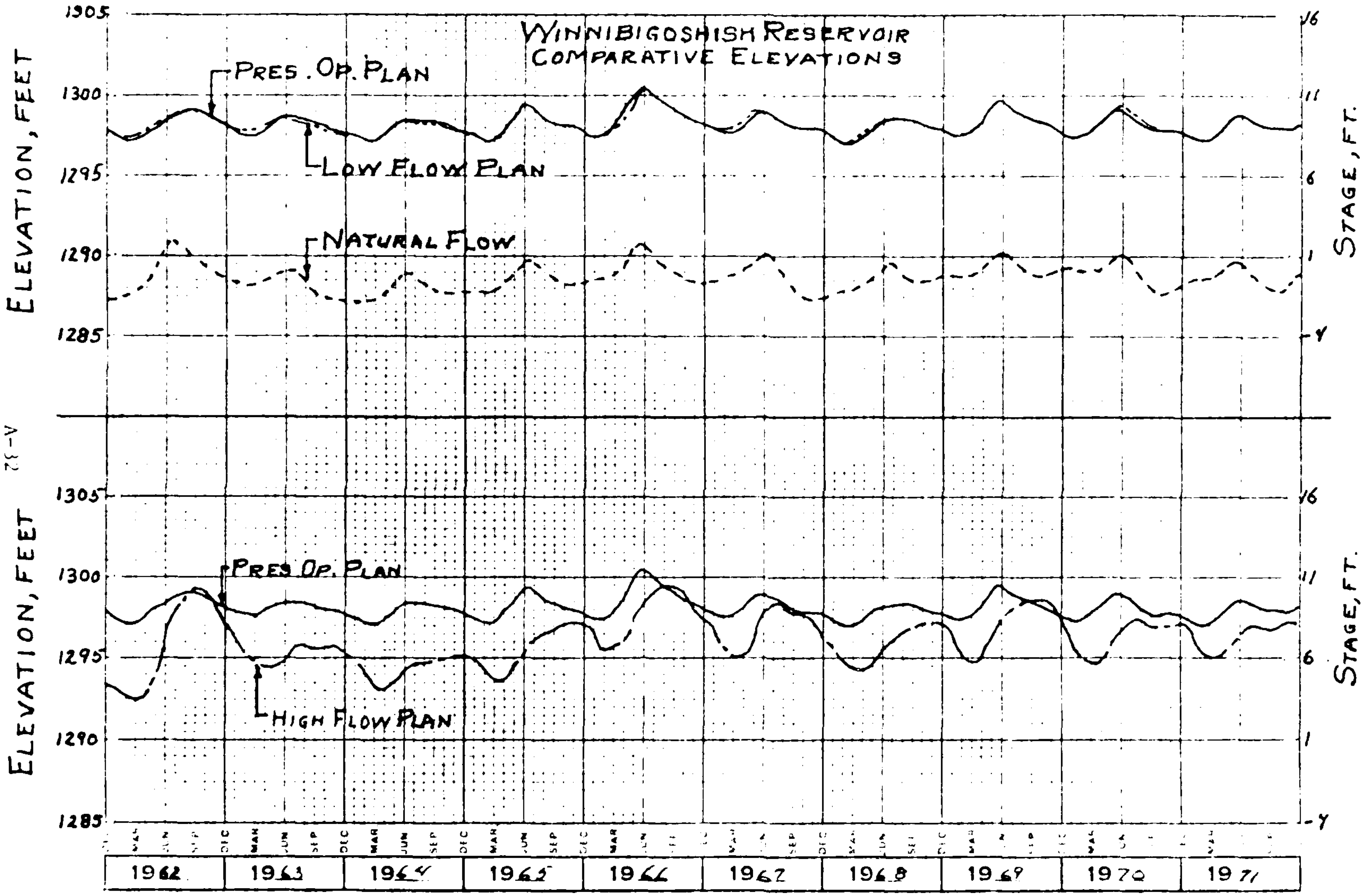
Examples of some of the stage 2 results are shown in the following figures.

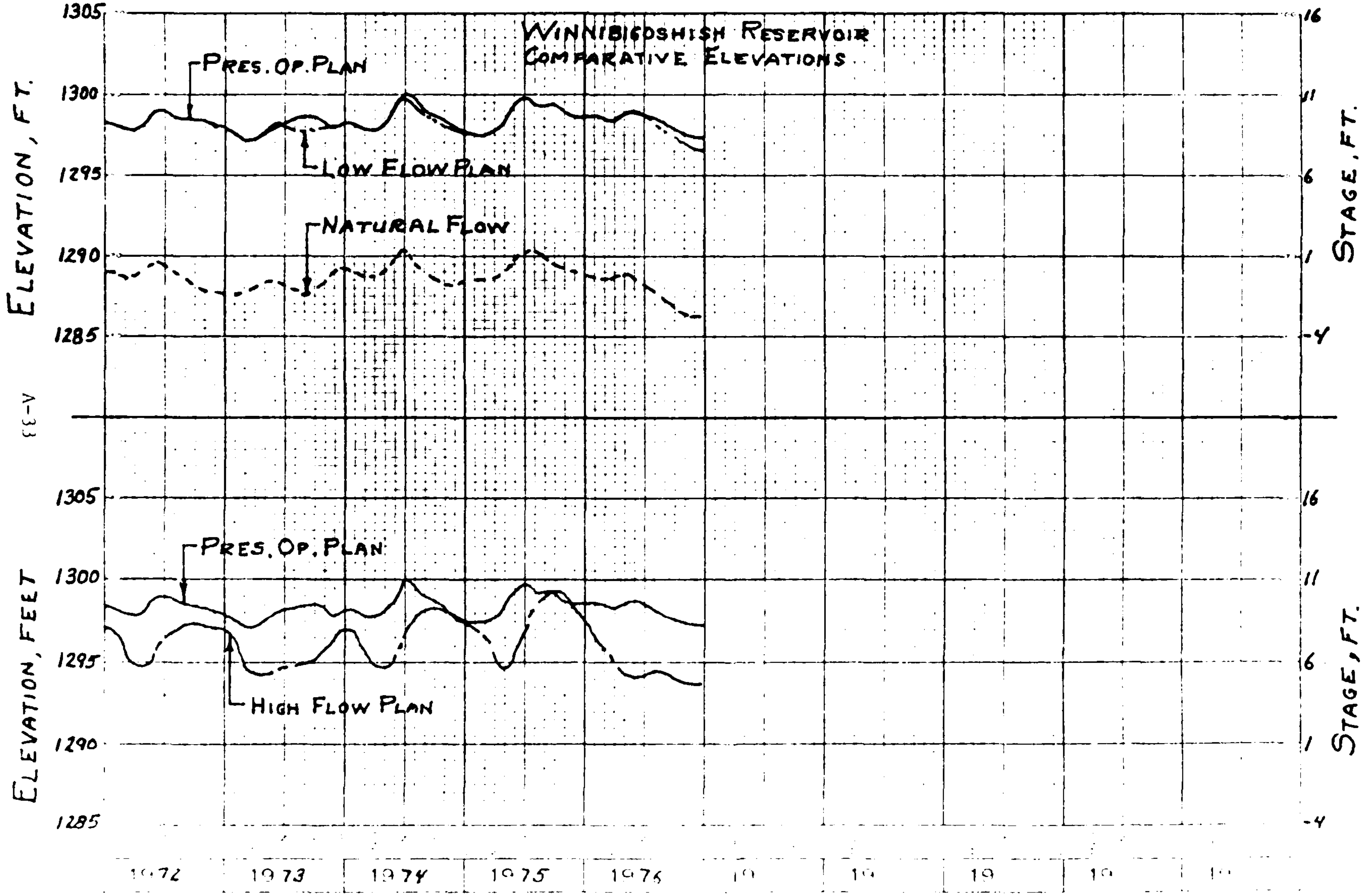

WINNIBIGOSHISH RESERVOIR
COMPARATIVE ELEVATIONS
PRESENT OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
HIGH FLOW PLAN
ELEVATION, FEET
STAGE, FT.
1305
1300
1295
1290
1285
16
11
6
1
-4
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941


WINNIBIGOSHISH RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
HIGH FLOW PLAN
ELEVATION, FEET
STAGE, FT.
1305
1300
1295
1290
1285
16
11
6
1
-4
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951

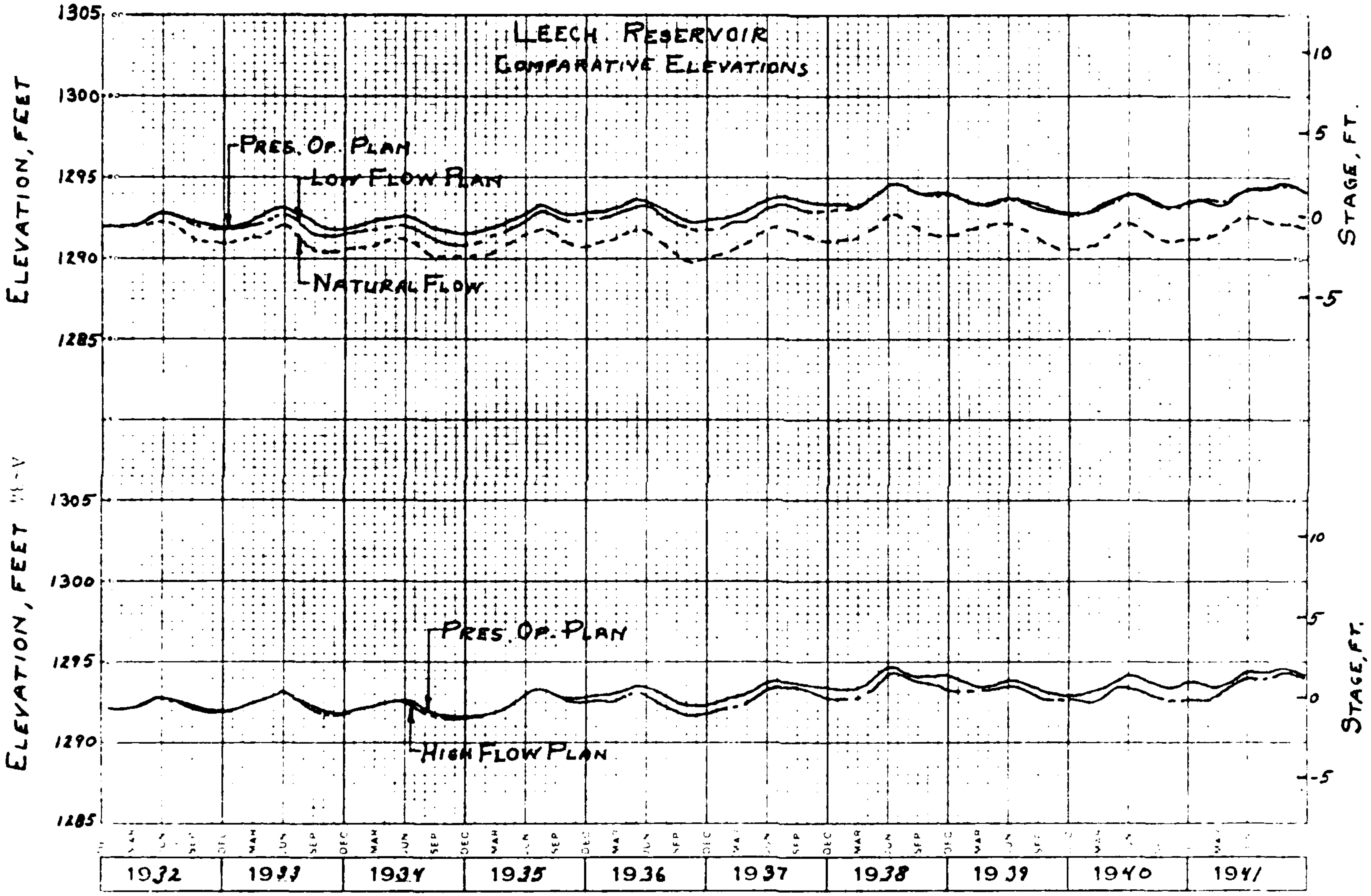


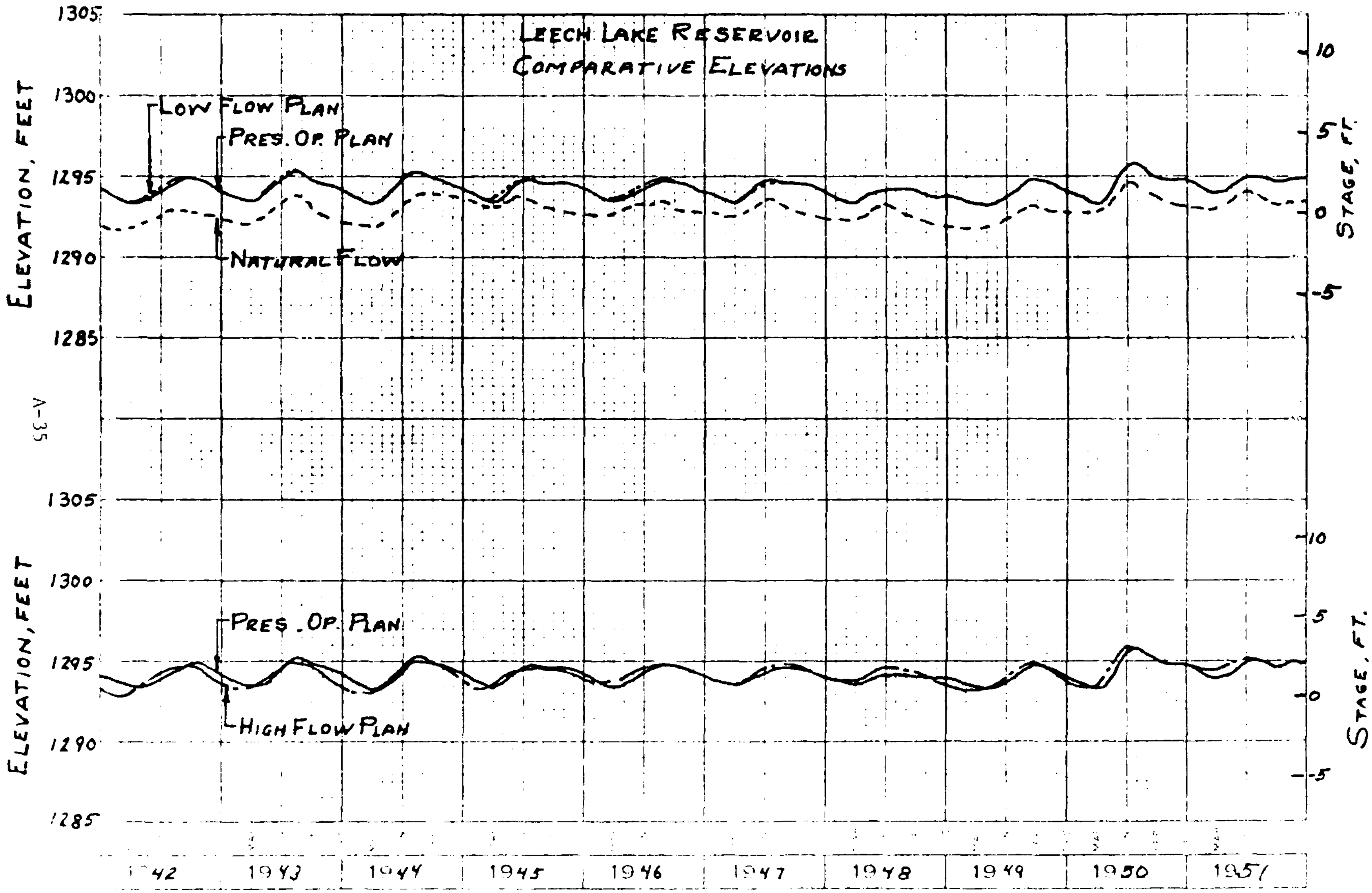
WINNIBIGOSHISH RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
PRES. OP. PLAN
HIGH FLOW PLAN
ELEVATION, FEET
ELEVATION, FEET
STAGE, FT.
STAGE, FT.
1305
1300
1295
1290
1285
1305
1300
1295
1290
1285
16
11
6
1
-4
16
11
6
1
-4
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961


WINNIBIGOSHISH RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
PRES OP. PLAN
HIGH FLOW PLAN
ELEVATION, FEET
STAGE, FT.
1305
1300
1295
1290
1285
16
11
6
1
-4
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971

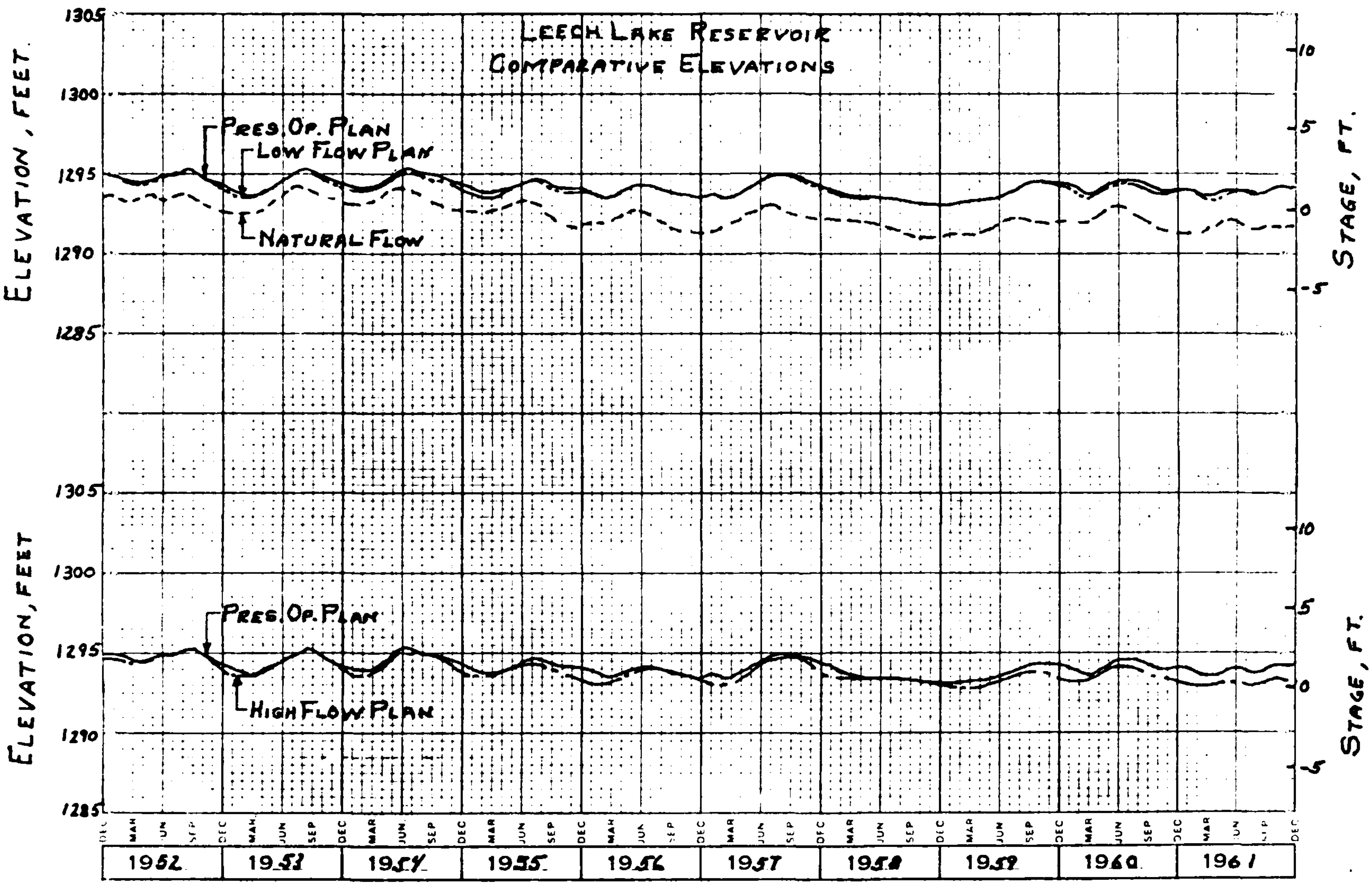


WINNIBIGOSHISH RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
HIGH FLOW PLAN
ELEVATION, FT.
ELEVATION, FEET
STAGE, FT.
1305
1300
1295
1290
1285
16
11
6
1
-4
1972
1973
1974
1975
1976
19

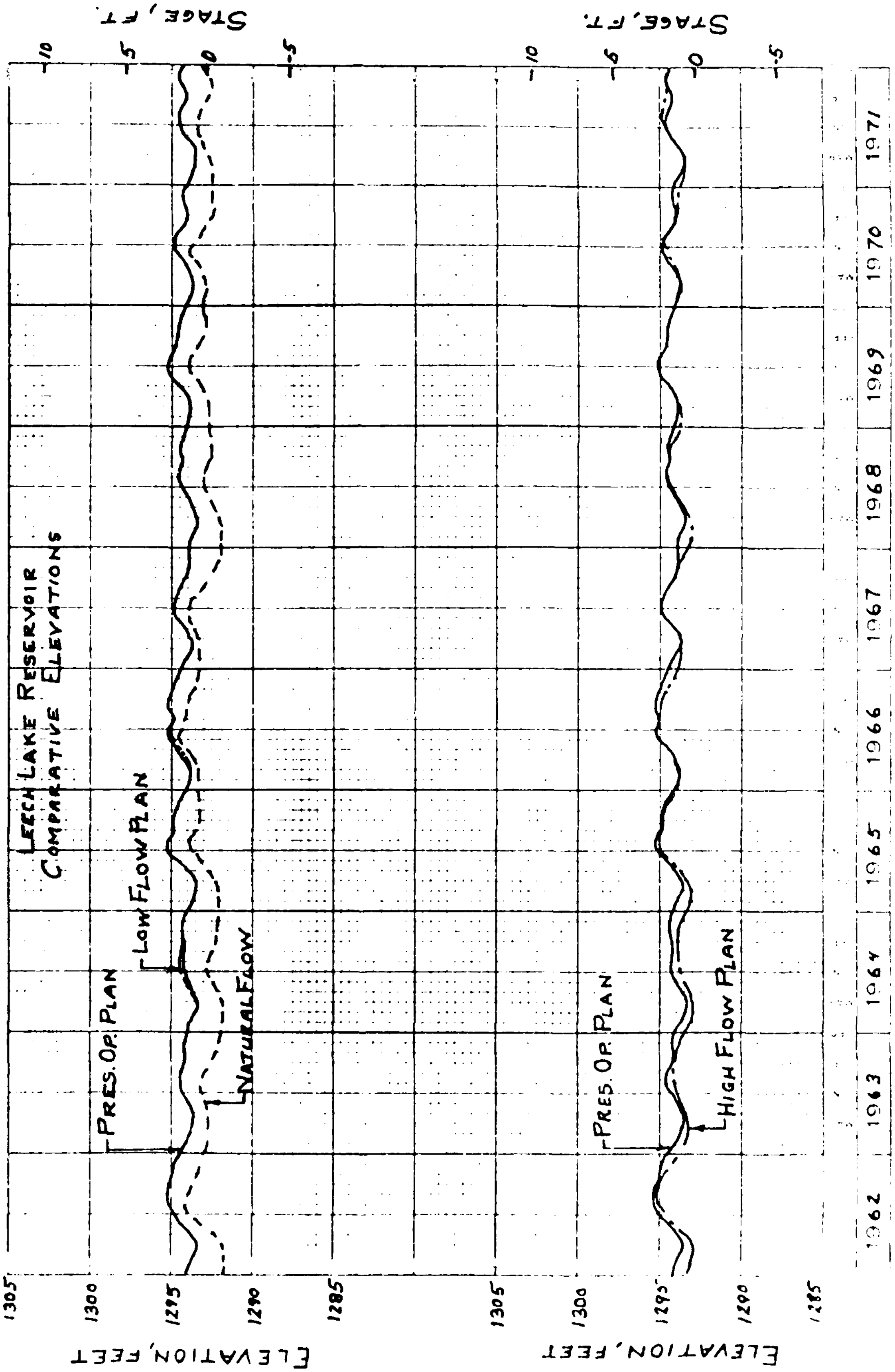

LEECH RESERVOIR
COMPARATIVE ELEVATIONS
ELEVATION, FEET
STAGE, FT.
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
HIGH FLOW PLAN
1305
1300
1295
1290
1285
10
5
0
-5
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941



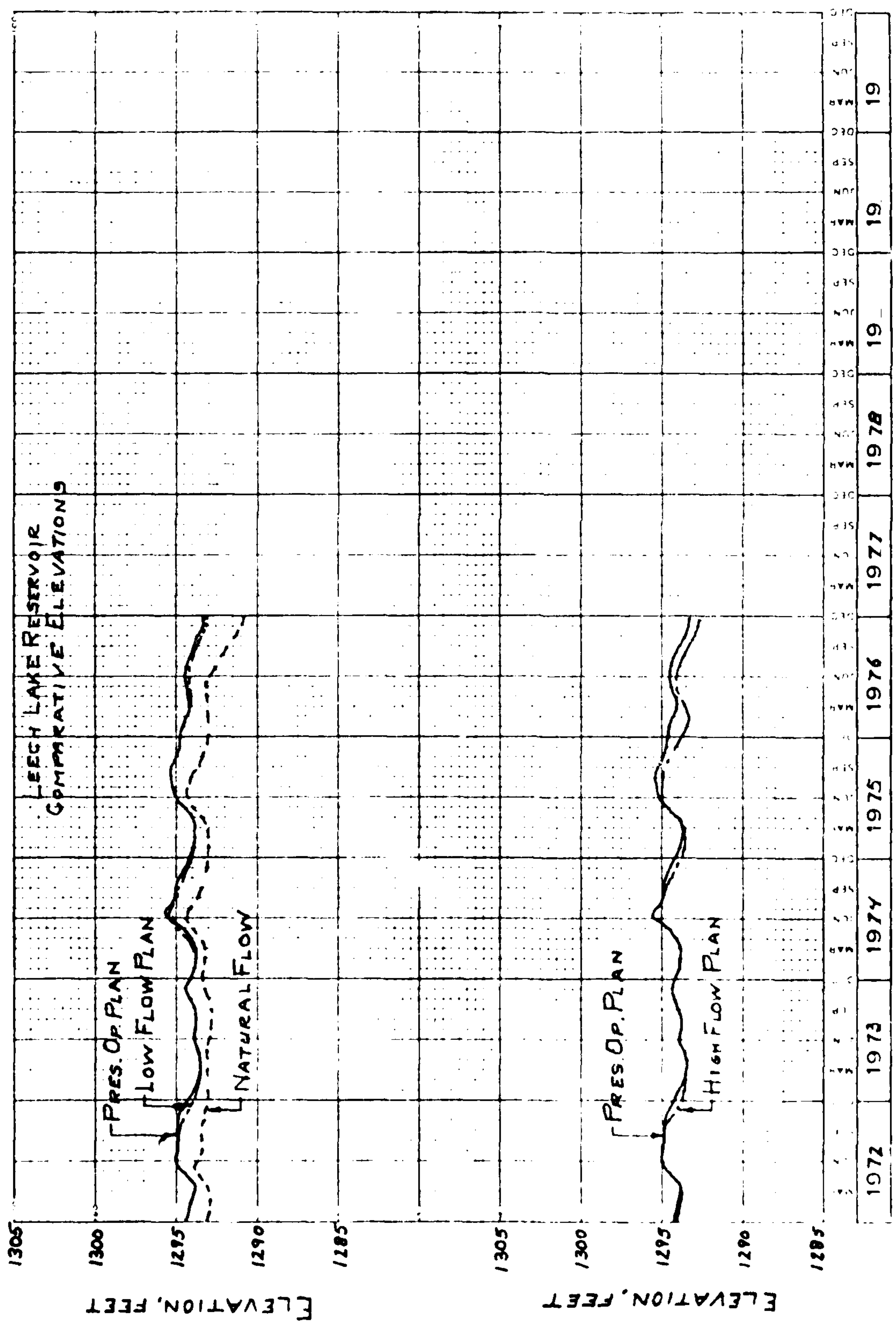
LEECH LAKE RESERVOIR
COMPARATIVE ELEVATIONS
LOW FLOW PLAN
PRES. OP. PLAN
NATURAL FLOW
PRES. OP. PLAN
HIGH FLOW PLAN
ELEVATION, FEET
ELEVATION, FEET
STAGE, FT.
STAGE, FT.
1305
1300
1295
1290
1285
1305
1300
1295
1290
1285
10
5
0
-5
10
5
0
-5
42
1943
1944
1945
1946
1947
1948
1949
1950
1951



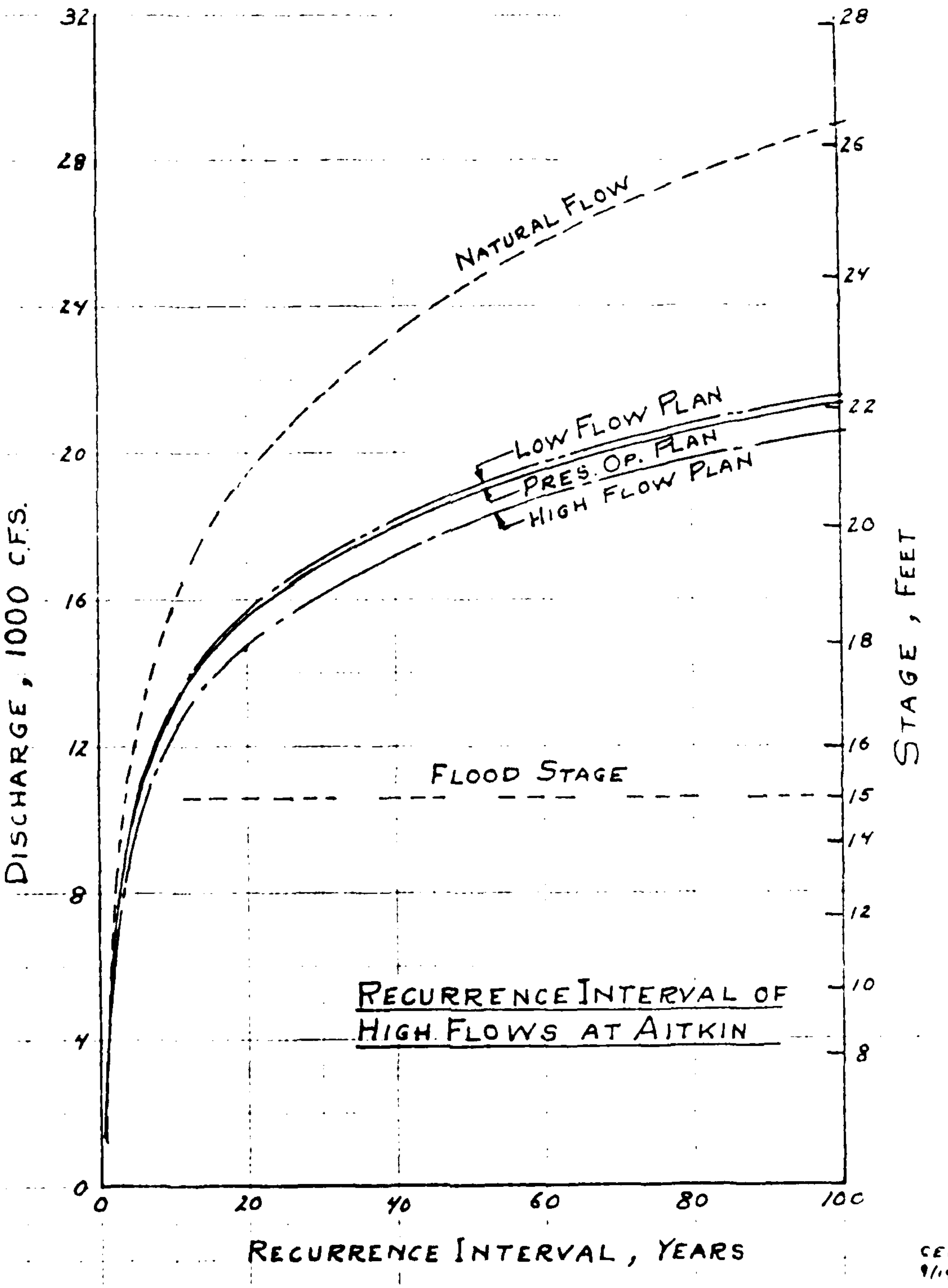
LEECH LAKE RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
PRES. OP. PLAN
HIGH FLOW PLAN
ELEVATION, FEET
STAGE, FT.
1305
1300
1295
1290
1285
10
5
0
-5
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961



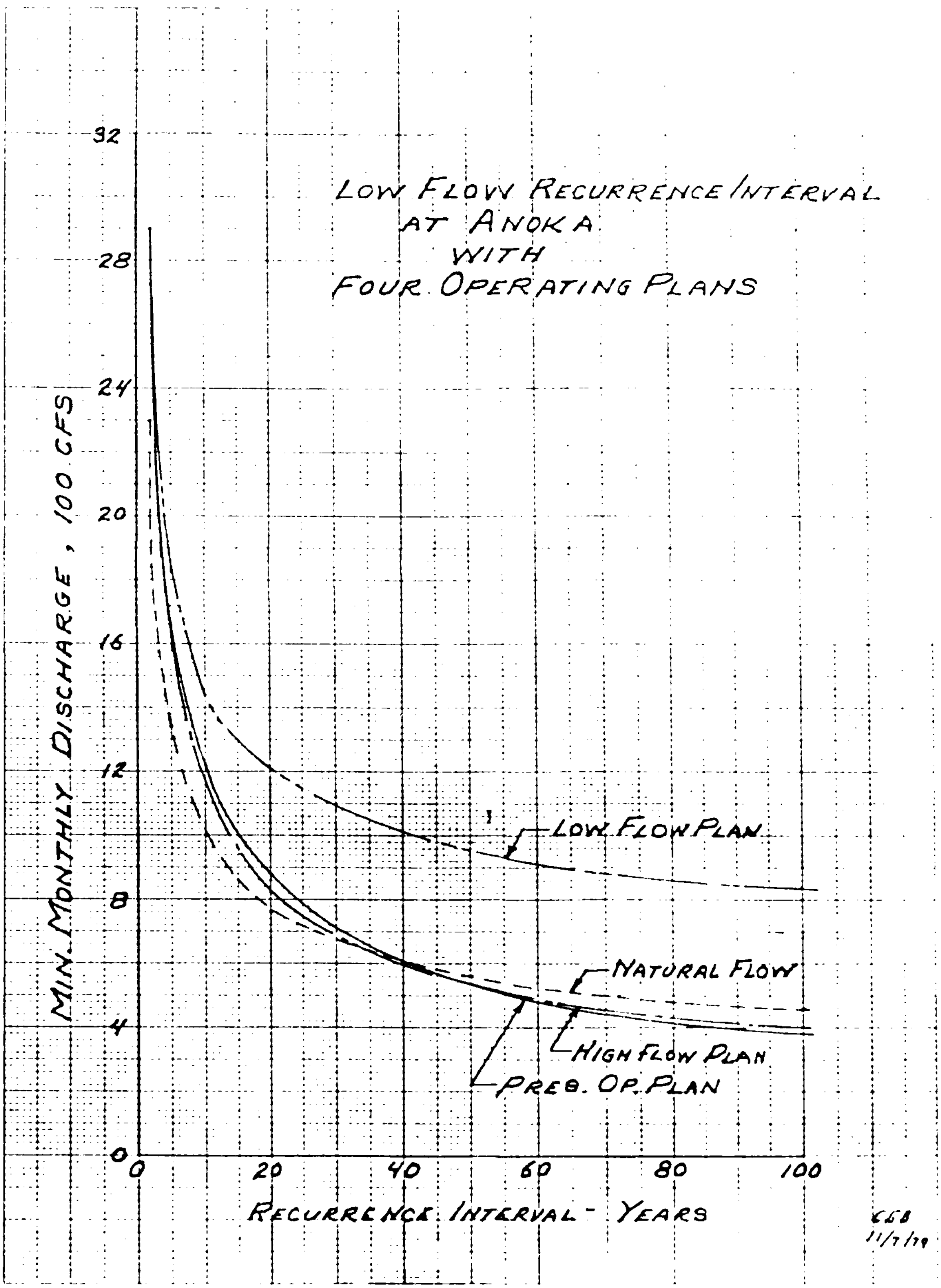
LEECH LAKE RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
PRES. OP. PLAN
HIGH FLOW PLAN
STAGE, FT.
STAGE, FT.
ELEVATION, FEET
ELEVATION, FEET
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1305
1300
1295
1290
1285
-10
-5
0
5



LEECH LAKE RESERVOIR
COMPARATIVE ELEVATIONS
PRES. OP. PLAN
LOW FLOW PLAN
NATURAL FLOW
PRES. OP. PLAN
HIGH FLOW PLAN
1972
1973
1974
1975
1976
1977
1978
19_
19
19
1305
1300
1295
1290
1285
1305
1300
1295
1290
1285
ELEVATION, FEET
ELEVATION, FEET



32
28
24
20
16
12
8
4
0
28
26
24
22
20
18
16
15
14
12
10
8
0
20
40
60
80
100
NATURAL FLOW
LOW FLOW PLAN
PRES. OP. PLAN
HIGH FLOW PLAN
FLOOD STAGE
RECURRENCE INTERVAL OF
HIGH FLOWS AT AITKIN
DISCHARGE, 1000 CFS.
STAGE, FEET
RECURRENCE INTERVAL, YEARS


LOW FLOW RECURRENCE INTERVAL
AT ANOKA
WITH
FOUR OPERATING PLANS
MIN. MONTHLY DISCHARGE, 100 CFS
RECURRENCE INTERVAL - YEARS
LOW FLOW PLAN
NATURAL FLOW
HIGH FLOW PLAN
PRES. OP. PLAN
0
4
8
12
16
20
24
28
32
0
20
40
60
80
100
CEB
11/7/79

Conclusions

Conclusions were developed from the following summary table prepared as a result of the HEC-5c computer work. The HEC-5c work is described in an August 1979 report prepared by SAFHL. The summary table compares total average annual flood damages developed by manual methods by the St. Paul District and May-September annual damages developed manually in connection with a contract HEC-5c computer study. The May-September annual damages include both high and low water damages on the six headwaters lakes. The method of development is described in the subsequent stage 3 analysis section.

Operating plans - comparison
of average annual high and low water losses (SAFHL)

Area or location	St. Paul District average annual high water damages Present plan	Plan 1-present plan	Plan 2-Twin Cities low-flow plan	Plan 3-Aitkin flood control (high-flow) plan	Plan 4-natural conditions
Headwaters lakes					
Winnibigoshish	$32,500	$32,460	$29,867	$72,746	$97,440
Leech	100,000	96,085	125,096	126,445	499,[illegible]
Pokegama	53,600	68,840	68,262	65,271	55,[illegible]
Sandy	92,300	96,836	92,557	196,293	407,848
Pine River	150,000	33,425	95,580	33,338	698,30[illegible]
Gull	236,000	120,140	164,855	128,155	[illegible]
Total headwaters lakes	664,400	447,786	576,217	622,248	2,20[illegible],1[illegible]7
Headwaters lakes damages upstream of Aitkin (first four lakes only)	278,400	294,221	315,782	460,[illegible]55	1,060,501
Aitkin area					
Residential					
Urban Aitkin	34,100	--	--	--	--
Rural (non-farm)	14,700	--	--	--	--
Agricultural					
Crop damage	93,900	--	--	--	--
Other agricultural	59,400	--	--	--	--
Total Aitkin	202,100	309,600	300,520	2[illegible]2,560	[illegible]
Aitkin plus six headwaters lakes	866,500	757,386	876,737	894,808	2,[illegible]
Anoka	--	4,488,500	1,104,100	3,631,800	6,119,[illegible]
Total		5,245,886	1,980,837	4,526,608	8,[illegible]

The preceding table shows that the present operating plan (HEC-5c study) is the most attractive of the four plans evaluated if only the damages at Aitkin and the six headwaters lakes are considered. The present operating plan with approximately $757,000 damages ranks first, the low-flow plan with approximately $877,000 losses is second, and the high-flow plan with $895,000 average annual damages is third.

If the water needs at the Twin Cities (Anoka) are included, a different ranking occurs. The low-flow plan ranks first at $1,981,000, the high-flow plan is second with $4,527,000, and the present operating plan is third with $5,246,000 in average annual damages. The return to natural conditions ranks last under either set of circumstances.

Clearly, the Anoka losses are not really "damages" but potential losses to water supply at Anoka from an inability to maintain an assured minimum flow of 1,600 cfs at that location.

The low-flow plan appears most desirable if equal weight is given to Twin Cities water supply measured at Anoka and to flood and low water damage upstream. However, the present plan of operation appears to be the best plan for minimizing Aitkin and headwaters high- and low-water damages.

An additional benefit not considered in the low-flow plan could be realized from a low-flow release schedule for the Twin Cities. This benefit would result from reduced wastewater treatment costs at a guaranteed minimum flow at St. Paul. The present 7-day, 10-year low-flow would need to be raised to derive this benefit as discussed under "Low Water Damages" in the subsequent damage section of this appendix. There could also be an added benefit for hydroelectric power at 14 existing generating plants, as discussed in the same cost estimate analysis.

Environmental losses for the four plans were not included in the stage 2 analysis.

STAGE 3 STUDIES

General

The stage 2 work conducted by SAFHL encountered a number of problems in trying to use the earlier HEC-5c program. These problems were not resolved, although SAFHL was able to complete its evaluation of plans 1 through 4 by splicing together parts of runs and by considerable manual work, especially on graphic plots.

Stage 3 work was directed toward reevaluating the effects of the four operating plans previously evaluated in stage 2 and six additional operating plans which were suggested in or inferred from agency or public comment. The stage 3 work used a newer HEC-5 model developed by the Hydrologic Engineering Center (HEC) in Davis, California, a new statistical data program for time series data frequency analysis, and the HEC Expected Annual Flood Damage Program. The computer results from these programs determined the hydraulic and economic effects of implementing each of the evaluated plans.

The HEC-5 program was extensively revised by HEC before the stage 3 contractor, Anderson-Nichols & Company (ANCO), attempted to use the program. These revisions were necessary to ensure that the reservoir operation logic was performing properly. The revisions were completed in the fall of 1981.

Problems with the HEC-5 runs in January 1982 led to an iterative process review by HEC. After considerable time and effort, 12 major problems were discovered and corrected and final stage 3 runs were made. Unfortunately, a last problem was discovered in the plan 2 results after final runs were made and too late for modification to meet contract and study obligations. This problem was subsequently corrected by HEC, but the plans 2, 5, and 6 results in this report still contain the problem.

The problem shows up in the low-flow release plans calling for 1,600, 2,275, and 4,800-cfs minimum flows at Anoka. In effect, the problem prevented some releases that should have been made from the three upper lakes to supply these flows. The problem is not large, but does affect the hydraulic, frequency, and economic results. The expected damage at the three upper lakes should be somewhat larger, and the Anoka requirements should be met more often for plans 2, 5, and 6.

ANCO's analysis is contained in a June 1982 report entitled "Computer Operations Study of Reservoir Operations for Six Mississippi River Headwaters Dams, Contract No. DACW37-81-C-0027." No attempt will be made to include the results of the ANCO report in this appendix as the ANCO report is, by reference, made a part of this report. However, the time series data plots and maximum and minimum data tables for plan 1, the present plan of operation, are included in this appendix for reference (see plates A-38 to A-60).

Plans Evaluated

- Plan 1 - present operating plan. This plan simulates as closely as possible the current operating plan for each of the six Mississippi River Headwaters Lakes.

- Plan 2 - low-flow plan (water supply plan for the Twin Cities). This plan would insure a minimum flow of 1,600 cfs at Anoka. For further illustration, the 1,600-cfs flow of plan 2 would provide a net 1,350-cfs flow in the Mississippi River under 1970 conditions and a net 850-cfs flow in the Mississippi River in 2015, after total Twin Cities withdrawals. In comparison, the 7-day 10-year flow at St. Paul, based on past U.S. Geological Survey records, varies from about 1,340 cfs to 1,430 cfs (depending on whether a longer or shorter period of record is used). Thus, alternative 4 would meet the 7-day 10-year low-flow requirements of St. Paul for 1970, but would be increasingly deficient in that regard for subsequent years.

- Plan 3 - high-flow plan or 15-foot desirable maximum stage at Anoka (zero damage in the urban area). The four farthest upstream lakes would be operated to protect Aitkin insofar as is possible.

- Plan 4 - Natural conditions. The six lakes would be allowed to fluctuate as they did in nature with no control structures present.

- Plan 5 - low-flow plan with 2,275-cfs minimum at Anoka. This alternative would be similar to plan 2, except the minimum desirable flow at Anoka would be raised from 1,600 to 2,275 cfs.

In letters dated 2 May 1978, the Environmental Protection Agency and the Metropolitan Waste Control Commission both requested evaluation of an alternative with flows of approximately this magnitude. This alternative would ensure 1,875 cfs at St. Paul after Twin Cities water withdrawals are made. This would be a combined water supply and water quality alternative for supplying year 2000 water needs identified by the June 1977 Minneapolis-St. Paul Level B Study.

- Plan 6 - low-flow plan with 4,800-cfs minimum at Anoka. This alternative would increase the minimum flow at Anoka to 4,800 cfs, using the entire "Present Operating Limits" storage space to provide this flow whenever possible.

In a letter dated 23 May 1978, the Metropolitan Council requested the Corps of Engineers to evaluate a plan which would provide 4,000 cfs at St. Paul (in addition to Twin Cities water withdrawals). A 4,000-cfs guaranteed minimum low flow at St. Paul would require a delivered flow at Anoka of 4,200 cfs in 1970 and 4,800 cfs in 2015. The purpose of the guaranteed St. Paul low flow of 4,000 cfs would be to provide an assured water supply and water quality improvement in the Twin Cities area and to decrease the required level of sewage treatment (for example, 1983 water quality standards could possibly be maintained without tertiary treatment if the St. Paul 7-day 10-year low-flow were equal to 4,000 or 5,000 cfs).

● Plan 7 - hydropower. This alternative would optimize hydropower production at existing power plants on the Mississippi River upstream of the Twin Cities metropolitan area. It was decided for the purpose of the study that plan 7 would be identical to plan 6 with a desirable minimum flow of 4,800 cfs at Anoka.

● Plan 8 - minimize lake property damage. This alternative should come close to the present operating plan, plan 1. Potential changes would minimize lake damages, particularly during the recreational season from May to September. No attempt would be made to protect downstream interests at the expense of the lake property owners.

● Plan 9 - environmental or conservation plan. This plan again is quite similar to the present operating plan. Four of the six lakes would be operated as they are now. Leech Lake would be operated to follow the low side of the present summer operating band. Generally speaking, a relatively stable level would be required to accommodate wild rice production (see appendix F).

The conservation plan for Lake Winnibigoshish would consist of the present trial operating plan to control lake erosion. This plan attempts to operate Lake Winnibigoshish between 9.0 and 9.5-foot summer levels, with a specific target level of 8.5 by 25 April to facilitate walleye spawning (see appendix B, pages B-45 to B-46a).

● Plan 10 - Sandy Lake plan. During spring floods, Sandy Lake gates would be removed from the water sooner to allow the pool and tail water to rise simultaneously from the spring drawdown level. Gates would be closed on the flood recession to maintain its normal pool. Sandy Lake pool is now regulated as it rises from spring drawdown level to normal summer pool because backwater effects from the Mississippi River influence both levels. The objective of the regulation change is to see if it produces any change in damage at Aitkin. The proposed operation change offers advantages to the operators in that it could eliminate considerable gate operation moves without materially changing downstream effects at Aitkin. (Plan 10 could not be evaluated with the HEC-5 program because of the Mississippi River backwater conditions that affect the Sandy Lake outlet.)

Added Modifications

Stage 3 work followed the same pattern as in stage 2 except for the following changes:

- A new contractor was selected to do the modeling study - Anderson-Nichols & Company of Palo Alto, California, located near the Hydrologic Engineering Center in Davis.

- The period of record was extended to include 1930 and 1931. These two years were eliminated in stage 2 work because of the lack of U.S. Geological Survey gage records at Anoka. ANCO developed flows at Anoka for these 2 years from three area gages (Elk River, St. Paul, and Mankato).

- The St. Paul District modified the stage-damage relationship at Aitkin from that used in the SAFHL stage 2 study. Monthly agricultural damage curves were modified into a single composite damage curve for use by the HEC-5 computer program.

- Some criteria adjustments were made to the basic four operating plan pool levels and release schedules developed in the earlier stage 2 analysis by SAFHL. For example, the normal summer pool level for Lake Winnibigoshish for the flood control plan (plan 3) was 10.0 to 10.5 feet in the stage 2 analysis and 9.0 to 9.5 feet in the stage 3 analysis. This adjustment was needed to make the criteria consistent with other plans. Also, the supplementary low flows for plans 2, 5, and 6 in the stage 2 analysis were released from all six headwaters lakes. In the stage 3 analysis the supplemental low flows were released only from the upper three lakes - Winnibigoshish, Leech, and Pokegama. The upper three lakes have the most storage, and it was thought that this approach would be more realistic.

Damages

No structural works were recommended in this lake operating plan evaluation study; therefore, no cost estimate was required. However, a major study concern was to evaluate the potential downstream "losses" from an inadequate water supply versus the added upstream damages resulting from several different plans of lake operation. This section contains the development of average annual high water damages in the Mississippi River Headwaters Lakes and Aitkin area, based on actual past operation, compared with a combined high and low water damage analysis by computer program HEC-5 for 10 plans of operation. This economic analysis is essentially the same as the stage 2 analysis which used the HEC-5c program.

An economic analysis of the Mississippi River Headwaters Lakes operating plans was developed to compare lake area damages with prospective gains to downstream interests. Economic losses in each headwaters lake area were determined by either a field survey or through extrapolation of field survey and other available data. Losses in the downstream Aitkin area were derived through field survey and through updating observed losses from recent flood events. Potential gains from supplemental low flows for the Twin Cities area were derived from estimated water supply values. Additional monetary gains would result to the Twin Cities metropolitan area if low-flow augmentation for water quality were considered.

Elevation-damage curves were derived for each of the six headwaters lakes and for Aitkin and are shown on plates A-18 through A-27. An area flooded curve for the Aitkin agricultural area is shown on plate A-28. The elevation-damage curves for each of the six headwaters lakes show both the low and high water damage relationships. High water damages consist of flood fight or preparedness measures, damage and loss of personal property, and cleanup and repair for both residential and commercial units. In addition to the above damages, commercial establishments experience a decline in net income because of the high water. Loss of property from erosion is also reflected in the curves.

Low water damages consist of changes in net income to commercial activities. Some of these losses are increased expenditures for harbor maintenance, reduced or canceled reservations because of access problems to fishing areas, shortened stays because of poor fishing, and damaged equipment because of shallow depths. Private landowners also experience increased expenses and equipment damages from low water. Low water damages are especially severe on lakes with very gradually sloping bottoms.

Detailed damage surveys were conducted on Pokegama and Sandy Lakes and in the Aitkin area. Damage estimates for the four remaining headwaters lakes were made without detailed surveys, although a partial damage survey was conducted of Leech Lake and adjoining lakes. The partial survey of Leech Lake included interviews with owners of all commercial properties. A resume of the damage surveys follows.

Pokegama Lake Area. - Pokegama Lake area properties were inventoried along approximately 60 miles of shoreline during June 1977. Each visible unit was photographed, sighted with a hand level, and located on a U.S. Geological Survey quadrangle map. Approximately 800 photographs were taken of 966 shoreline units. Residential units comprise 896 of the units. The remaining 70 units were privately owned, belonging to 15 commercial holdings such as resorts.

The survey was supplemented by a 3-day "open-house" conducted at Pokegama Dam, damage interviews conducted at a Pokegama Property Owners Association meeting, and results of a questionnaire mailed out by the Pokegama Property Owners Association in its July 1977 newsletter.

Sandy Lake Area. - Sandy Lake property was inventoried in a manner similar to Pokegama Lake. The survey on Sandy Lake was conducted along approximately 82 miles of shoreline during September 1977. Each visible unit was photographed, sighted with a hand level, and located on a U.S. Geological Survey quadrangle map of the area. Over 700 photographs were taken, showing 904 private and 12 resort/commercial units. The survey was supplemented by a field sample survey distributed to approximately 150 property owners and by interviews with most of the owners of the 12 commercial units.

Leech Lake Area. - In June 1978 a damage survey was conducted of all commercial establishments on all lakes affected by the operation of Leech Lake Dam. During the survey, 107 property owners were contacted, which represents a 99-percent sample. Each property owner was asked to describe and quantify damages, changes in operating procedures, and changes in net income resulting from the 5 July 1975 high water and the 1977 low water. Private property damages on Leech and adjoining lakes were estimated as described in the following paragraph for Winnibigoshish, Pine River, and Gull Lakes. An estimated 1,493 private properties are around Leech Lake and principal connecting bays.

Winnibigoshish, Pine River, and Gull Lakes. - Damage estimates for the three remaining headwaters lakes were made without field surveys. Estimates were based on the number of property units around each lake as shown on U.S. Geological Survey quadrangle sheets. These totals were further increased by 28.5 units per year, from the date of the quadrangle sheet to date. The 28.5-unit annual growth rate was the average rate determined for Sandy and Pokegama Lakes from the year of their quadrangle sheets to the 1977 field survey. The number of commercial units for each of the three lakes was obtained from representatives of the Mississippi River Headwaters Association. Total commercial and private properties on these three lakes are as follows:

Lake area	Number of units: Private	Number of units: Commercial
Winnibigoshish	452	16
Pine River	2,139	88
Gull	1,480	27
Total	4,071	131

Aitkin Area. - Field surveys were conducted of the Aitkin agricultural area in August 1977. A survey sample was made of 20 to 30 percent of the area farmers. Approximately 45 farm units and 35 other rural residential units are in the Aitkin study area. No economic damage field surveys were made for urban Aitkin because sufficient information was available from prior surveys. About 200 homes and 44 business establishments are subject to flood damage in the area as indicated by the 1950 flood.

Twin Cities Area. - No field surveys were necessary in the Twin Cities area as the headwaters lakes are located too far upstream to have any appreciable effect on flood stages at this downstream location. Estimates of low-flow benefits to the Twin Cities were based on a dollar value per cubic foot per second for emergency water supply or for water quality control, depending on the alternative plans under evaluation.

High water damages were developed manually for each of the six headwaters lakes and the Aitkin area as described below.

Pokegama Lake. - The findings of the Pokegama damage survey are as follows:

a. A substantial reduction in the number of commercial establishments has occurred so that low water damages (loss of business) will be minimal (33 commercial businesses in 1962 versus 15 commercial businesses in 1977).

b. Approximately 78 houses will receive some water damage from a 100-year flood (elevation 1278.2). Approximately 8.6 percent of the residential units are flooded at this elevation.

c. Approximately $200,000 in flood damage (1977 dollars) would occur to buildings, contents, and yard facilities at the 100-year flood elevation of 1278.2.

d. Another loss from high water and winds in the Pokegama Lake area results from shoreline erosion. This problem is particularly severe along Stony Point and the southeast arm of Wendigo Bay. The current average annual shoreline erosion loss on Pokegama Lake is estimated at $1,900.

e. In general, only minor damage occurs with moderately high water except where high water is coupled with high winds. The principal damage for most units, at 100-year flood levels, is due to debris cleanup time and effort.

f. In summary, average annual high water damage on Pokegama Lake is $53,600 in October 1977 price levels. This amount includes all physical damage to property from high water levels, such as repair costs to docks and shore facilities and loss of business to commercial units, and $1,900 estimated annual shoreline property erosion loss. Average annual damages are developed as a standard method of comparison for all Corps of Engineers studies and are derived for Pokegama Lake and other lakes by summarizing the damage-frequency probabilities for each lake.

Sandy Lake. - The findings of the Sandy Lake damage survey are as follows:

a. A substantial reduction in the number of commercial establishments has occurred so that low water damages (loss of business) will be minimal (23 commercial units in 1962 versus 12 commercial units in 1977).

b. Approximately 79 homes will receive some damage from a 100-year flood (elevation 1223.9). Approximately 8.6 percent of the residential units are flooded at this elevation.

c. At the 1975 flood elevation of 1222.1, approximately $134,000 damage would occur from damages to buildings and contents and from cleanup costs.

d. The estimated average annual high water loss in Sandy Lake area shoreline value due to current erosion is $41,800.

e. In summary, average annual high water damage on Sandy Lake is $92,300 in October 1977 price levels. This amount includes all physical damage to property from high water levels, such as repair costs to docks and shore facilities and loss of business to commercial units, and $41,800 estimated annual shoreline property erosion loss.

Winnibigoshish, Leech, Pine River, and Gull Lakes. - Flood damage estimates for each of the four remaining lakes were made using the total number of units.

a. An elevation-damage relationship was first established for Pokegama and Sandy Lakes using a previously developed elevation-frequency curve and three elevations as plotting points for each lake as follows: (1) zero damage, (2) 1975 spring high water, and (3) 1965 high water on Sandy Lake and 1975 summer high water on Pokegama Lake. Damages per residential unit for Pokegama Lake were then derived from the developed elevation-damage curve for a 100-year flood. The 100-year average unit damages were then applied to the total units previously determined for the remaining four lakes. The total 100-year damages thus developed were used to establish a damage-frequency curve for each lake which also included the items listed in b. through d. below.

b. Damages to commercial property were established in the same manner as those for residential property as described in item a, except those for Leech Lake. A damage survey of 107 commercial properties on Leech Lake and connecting flowages was conducted in June 1978. This information was used to develop both high and low water commercial damages for the lake. The type of damage sustained by those interviewed is as follows:

Number of commercial property owners interviewed	Type of damage reported
14	High water damage only
23	Low water damage only
52	Both high and low water damage
18	No damage
107	

c. Facility and structural damage for each of the four lakes was estimated based on per unit facility and structural damages developed for Sandy Lake. The development around Sandy Lake is more like that of the other four lakes than that around Pokegama Lake which is primarily year-round residential.

d. Cleanup damages at each of the four lakes were based on cleanup damages for Pokegama Lake, which has similar water quality, as opposed to Sandy Lake water which is high in sediment, color, and iron content.

e. Public damages (damage to roads and other public facilities) were estimated at 7 percent of calculated damages for each of the four lakes. (Public damages were not obtained for Pokegama Lake and were also estimated at 7 percent.) Sandy Lake public damages were 13.6 percent of

calculated damages, but are exceptionally high because Sandy Lake has so many islands with low access and easily damaged roadways. The 7-percent figure was considered more realistic for the other five headwaters lakes.

f. Average annual current losses from shoreline erosion for the four lakes are as follows:

Lake	Estimated annual erosion loss
Winnibigoshish	$6,800
Leech	7,600
Pine River	2,800
Gull	400

These current losses are included in the average annual damage estimates for each lake.

g. Average annual damages developed from the area under the damage-frequency curve for each of the four lakes are shown below in October 1977 price levels.

Lake	Average annual high water damage
Winnibigoshish	$32,500
Leech	100,000
Pine River	150,000
Gull	236,000

These figures include estimated values of current annual shoreline property losses. Damage-frequency curves for each of the six Mississippi River Headwaters Lakes are shown on plates A-29 through A-34.

Aitkin Area. - Preliminary findings of this survey are as follows:

a. Rural Aitkin. -

1. The agricultural community is a livestock area as opposed to merely a crop-producing area. Early spring flooding is detrimental to the livestock operations of most farms.

2. Fairly low flows will flood some agricultural lands.

3. The 1975 (13-year frequency) flood reduced some farmers' incomes by as much as one-third.

4. Rural Aitkin average annual damage totals are as follows:

Category	Average annual damages
Crops	$93,900
Other	59,400
Rural nonfarm	14,700
Total	168,000

b. Urban Aitkin. - Nearly 200 homes and 44 business establishments were flooded in 1950 with a resulting $180,000 in flood damages. [illegible] flood caused 1-foot higher levels in Aitkin than a 100-year [illegible]. Damages to urban Aitkin were $112,000 in 1965, which was about [illegible] flood occurrence. In summary, average annual damages are computed [illegible] approximately $34,100 and assume that no flood protection is provided by the existing emergency levee constructed by the St. Paul District in 1969. The $34,100 in average annual damages occurs in spite of the Aitkin flood control diversion channel constructed by the St. Paul District in 1957.

Summary of High Water Damages. - Average annual damages for each of the lakes would be a monetary benefit if they could be prevented through another means of operation. A comparison of the existing average annual high water damages experienced in the six headwaters lakes and the Aitkin area is as follows:

Headwaters lakes and Aitkin area, average annual high water damages

Area	Average annual damages (October 1977 price levels)
Headwaters lakes[1]	
Winnibigoshish	$32,500
Leech	100,000
Pokegama	53,600
Sandy	92,300
Pine River	150,000
Gull	236,000
Total headwaters lakes	664,400[2]
Aitkin	
Residential	
Urban Aitkin	34,100[3]
Rural (nonfarm)	14,700
Total residential	48,800
Agricultural (average annual flooded acres - 2,690)	
Seasonally weighted crop damage ($34.89 per acre)	93,900
Other agricultural damage[4] ($22.05 per acre)	59,400
Total agricultural	153,300
Total Aitkin	202,100

(1) Headwaters lakes damages upstream of Aitkin (first four lakes only) are $278,400.

(2) Includes damages to structures, building contents, and roads and other public facilities; cleanup costs; and loss of business for commercial units.

(3) Assumes the existing emergency dike provides no protection from floods.

(4) This category of damages includes all losses sustained by farm operators, except crop damages. Other types of agricultural damages include loss of production and damages to barns and other structures, livestock, machinery and equipment, stored crops, wells, fences, private roads and driveways, and other improvements.

A summary of current Aitkin area flood damages with respect to stage at the Aitkin gage (river mile 1056.0) is shown in the following table.

Stage[2] (feet)	Aitkin area damages[1] Urban Aitkin	Agricultural	Rural property
11.0	$10,000	$20,000	
12.0	20,000	55,000	
13.0	35,000	100,000	
14.0	50,000	180,000	
15.0	60,000	330,000	$16,000
16.0	80,000	530,000	44,000
17.0	100,000	740,000	100,000
18.0	120,000	940,000	140,000
19.0	170,000	1,140,000	163,000
20.0	300,000	1,340,000	175,000
21.0	450,000	1,540,000	180,000

(1) All damages are in October 1977 price levels.
(2) Gage zero = 1182.41 msl, 1929 adjustment.

Comments or conclusions concerning the existing plan of operation tables previously presented follow:

a. Flood damages at Aitkin and on the six Mississippi River Headwaters Lakes are significant.

b. A comparison of high water damages in the Aitkin area with damages in the four upper headwaters lakes area indicates that under current conditions both areas are damaged significantly on an average annual basis. The average annual high water damages for the four lakes located upstream from the Aitkin area are $278,400 compared to $202,100 for the Aitkin area. These damages are for the current plan of operation.

c. Average annual damages for the Aitkin area are about $76,000 less than for the four upstream headwaters lakes. Average annual Aitkin area flood damages are derived using plates A-35 through A-37.

d. Flooding at Aitkin results from the uncontrolled area located downstream of the headwaters lakes and upstream from Aitkin. For example, 95 percent of the initial 1975 flood peak at Aitkin resulted from the drainage area located downstream of Pokegama and Sandy Lakes dams.

e. For planning purposes, no benefits were claimed for the Aitkin urban area emergency levee. However, this levee could possibly protect urban Aitkin to the 100-year flood level with additional emergency work and pumping facilities. If that were the case, the $34,100 in average annual damages would be reduced by $29,600 for the Aitkin area if benefits were claimed for the emergency levee.

f. Current average annual shoreline erosion losses on the four headwaters lakes upstream from Aitkin were included in the previous tabulations. These potential erosion losses currently are estimated at $58,100 annually. Erosion losses are not well documented in terms of shoreline lengths and loss in depth per year. However, the erosion loss figures referred to in this section were developed in connection with problem 2, bank erosion control on the headwaters lakes. Erosion losses in that section were considered under three categories: (1) current erosion, (2) potential erosion to developed or potentially developable properties, and (3) potential erosion to all shoreline properties (all lands with onshore slopes greater than 5 percent). The annual erosion loss values referred to earlier are those developed for category (1).

Erosion damages for each lake were derived using an erosion index value system developed for Lake Winnibigoshish by the U.S. Forest Service in 1972 and applying this system to each of the six headwaters lakes. The index system provides for increased erosion loss values with each parallel increase in lake levels. The index system is used with

present dollar loss values, feet of erodible shoreline, and elevation-frequency curves for each lake to derive erosion losses for each lake. These erosion losses are included in the damage-frequency curves on plates A-29 through A-34. The dollar loss values per foot of shoreline, present feet of erodible shoreline, and elevation-frequency curves for each lake are also used in the problem 2 section of this report, and are presented in more detail in that section.

Low Water Damage

By definition, the low water damages for the six headwaters lakes occur during the May-September recreation season. These low water losses result from changes in net income to commercial interests.

The low water damages represented on elevation-damage curves for the six headwaters lakes are a gross estimate of a single event; i.e., short-term low water. A permanent change in operating plan (return to natural conditions) would actually result in a changed base condition. These changes would consist of one-time losses and gains to the existing properties, future income stream of commercial properties, potential damages to new development, and success of property owner adjustment to the new water level fluctuation. It is impossible to more accurately assess the actual damages with a change in operating plan to natural conditions (without dams) without first conducting a detailed review of existing development on each lake in relation to current lake bottom contours.

Increased water releases from the six headwaters lakes during low-flow periods would produce increased low water lake damages over those that would occur with the present plan of lake operation. A low water damage relationship with elevation for each of the lakes is shown on plates A-18 through A-23. The low water damages experienced for a particular plan of lake operation can be derived from these curves and

compared with the benefits of the plan of flow release to downstream interests, in particular the cities of Minneapolis and St. Paul. For example, a preliminary low-flow plan for emergency Twin Cities area water supply would maintain flows at Anoka above 1,600 cfs. Economic benefit values assigned to the plan were based on $385 for every cubic foot per second that must be supplemented to maintain the desired 1,600-cfs flow. The $385 per cfs is equivalent to $0.60 per 1,000 gallons, the consumer cost of Minneapolis water supplied to customers outside the city.

A higher release low-flow plan for maintaining water quality in the Twin Cities could also provide economic benefits. If 7-day, 10-year low flows at St. Paul could be increased from 1,400 cfs to 4,000 cfs, the annual tertiary waste treatment costs could be reduced by $12,500,000. The value of every cfs required to increase the 7-day, 10-year low flow from 1,400 cfs to 4,000 cfs is $8,250. The effects of this type of operating plan were evaluated in the third phase of the study (4,800 cfs at Anoka for the year 2015 to provide 4,000 cfs at St. Paul). It was not possible to provide the annual 4,800 cfs flow at Anoka with headwaters lakes releases. Water shortages would occur in 187 months (35 percent) of the total period of record at Anoka.

Additional benefits to 14 existing hydroelectric plants on the Mississippi River between the six headwaters lakes and the Twin Cities could result from higher sustained flows. The Federal Energy Regulatory Commission (FERC) has developed a program that can compare hydroelectric benefits for different sustained flows at specific control points. No attempt was made to use the FERC program in this study to determine added hydropower benefits attributable to the low flow release plans 2, 5, and 6. Copies of the HEC-5 input data required by FERC to use the program were not available in time. The FERC program could be used in the future, if desired.

The summary of average annual low water damages for each of the six headwaters lakes was prepared manually in connection with the HEC-5c computer study in stage 2 and with the Expected Annual Damage program in stage 3. Both high and low water damages were evaluated by means of the HEC-5 computer analysis for the headwaters lake operating plans. These high and low water damages were developed for the period 1930-1976.

Final Results

The following products resulted from the stage 3 study and are included in the June 1982 contractors report.

a. Plots of both low and high stage-frequency curves for each of the six headwaters lakes for the period 1930 to 1976 for each operating plan investigated. The curves were developed for the recreation season 1 May to 30 September.

b. Plots of high-flow frequency curves at Aitkin and plots of low-flow frequency curves at the Anoka gage for the period 1930-1976, for each of the plans investigated. The curves were developed for the recreation season 1 May to 30 September.

c. Plots of operating plan effects at the Aitkin [illegible] and at each of the six headwaters lakes for the period [illegible] each of the plans investigated.

d. Annual maximum and minimum data tables for Aitkin, [illegible] each of the six headwaters lakes for each plan investigated [illegible] to 1976 period of record.

e. Summaries of average annual damages at each of the six head-waters lakes, at Aitkin, and the Anoka gage for the operating plans evaluated. (Damages and benefits were developed at 6 5/8-percent interest and October 1977 price levels.)

Sample plots of items a, c, and d for the present plan of operation (plan 1) as described above are included at the end of appendix A (see plates A-38 to A-60).

It was intended to evaluate 10 separate operating plans for the six Mississippi River Headwaters Lakes at the start of the stage 2 and stage 3 studies. However, as the study progressed, it was determined that plans 6 and 7 were identical and that plan 10 could not be evaluated with the HEC-5 program because of the Mississippi River backwater conditions that affect the Sandy Lake outlet. Therefore, the data plots mentioned above are for only eight plans.

Summary Tables

The following summary tables were prepared as the result of the HEC-5 computer work by ANCO. As stated earlier, the complete work is described in the contractor's June 1982 report.

Damage summary ($1,000's)

Average annual damage	Plan 1	SAFHL plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 8	Plan 9
Winnibigoshish									
High stage	[illegible]	15.0	4.0	0.1	0.0	4.0	1.9	2.9	4.0
Low stage	[illegible]	17.5	16.6	73.3	90.1	28.0	46.1	8.0	10.8
Total	[illegible]	32.5	20.6	73.4	90.1	32.0	48.0	10.9	14.8
Leech									
High stage	11.0	16.8	10.6	9.6	0.6	10.6	12.3	1.7	7.6
Low stage	71.3	79.3	66.5	166.8	441.9	141.0	150.2	75.1	43.4
Total	82.3	96.1	77.1	176.4	442.5	151.6	162.5	76.8	51.0
Pokegama									
High stage	25.0	62.4	24.9	18.7	6.2	25.4	23.7	0.6	25.4
Low stage	2.8	6.4	8.1	14.0	50.2	12.6	29.8	4.5	4.5
Total	27.8	68.8	33.0	32.7	56.4	38.0	53.5	5.1	29.9
Sandy									
High stage	[illegible]	90.3	29.4	26.8	---	29.4	29.4	22.5	29.4
Low stage	2.1	6.5	2.1	111.9	---	2.1	2.1	4.7	2.1
Total	31.5	96.8	31.5	138.7	---	31.5	31.5	27.2	31.5
Pine									
High stage	16.6	16.6	16.6	16.6	0.0	16.6	16.6	5.8	16.6
Low stage	[illegible]	16.8	6.3	6.3	618.8	6.3	6.3	9.5	6.3
Total	22.9	33.4	22.9	22.9	618.8	22.9	22.9	15.3	22.9
Gull									
High stage	127.5	96.2	127.5	127.5	72.8	127.5	127.5	66.3	127.5
Low stage	15.2	23.9	15.2	15.2	426.0	15.2	15.2	21.0	15.2
Total	142.7	120.1	142.7	142.7	498.8	142.7	142.7	87.3	142.7
Aitkin									
High flow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	278.6	[illegible]	417.6	283.1
Total AAD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	640.2	575.9

[illegible]

[illegible]

Plan	Average annual damages and benefits ($1,000's)					
	Average annual damages (AAD)			Net decrease in AAD (1)	Average annual net benefit Anoka	Total benefit (2)
	Six res.	Aitkin	Total			
1	320.9	278.6	599.5	--	--	--
2 (3)	327.8	278.6	606.4	(6.9)	2,559.5	2,552.6
3	586.8	218.8	803.6	(204.1)	(517.3)	(721.4)
4	1,706.6	469.5	2,176.1	(1,576.6)	(2,654.9)	(4,231.5)
5 (3)	418.7	278.6	697.3	(97.8)	6,034.3	5,936.5
6 (3)	461.1	277.7	738.8	(139.3)	12,852.1	12,712.8
8	222.6	417.6	640.2	(40.7)	(47.4)	(88.1)
9	292.8	283.1	575.9	23.6	227.4	251.0

(1) Relative to plan 1. Numbers shown in parentheses indicate increase in damages.
(2) Relative to plan 1. Numbers in parentheses indicate costs.
(3) Results include HEC-5 program problem as explained on pages A-44 and A-45.

The following summary table is included so the ANCO results can be conveniently compared with the earlier findings of the SAFHL study.

Operating plan comparison - average annual high and low water losses

	Operating plan (1977 prices)			
Area or location	Plan 1 - (present conditions)	Plan 2 - (water supply)	Plan 3 - (flood control)	Plan 4 - (natural conditions)
Headwaters lakes				
Winnibigoshish	$13,700	$20,600	$73,400	$90,100
Leech	82,300	77,100	176,400	442,500
Pokegama	27,800	33,000	32,700	56,400
Sandy	31,500	31,500	138,700	---
Pine River	22,900	22,900	22,900	618,800
Gull	142,700	142,700	142,700	498,800
Total headwaters lakes	320,900	327,800	586,800	1,706,600
Four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy)	155,300	162,200	421,200	589,000
Aitkin	278,600	278,600	216,800	469,500
Aitkin plus six headwaters lakes	599,500	606,400	803,600	2,176,100
Anoka	3,189,900	630,400 (1)	3,707,200	5,844,800
Total	3,789,400	1,236,800	4,510,800	8,020,900

(1) Should be zero. No water shortage occurred at Anoka during the testing period of the study. However, when production runs were made, a slight problem occurred. The problem was corrected by HEC but the correction was made too late in the study to rerun plans 2, 3, and 4.

Operating plan comparison - average annual high and low water losses (cont)

Area or location	Plan 5 - (2275-cfs flow plan)	Plan 6 - (4800-cfs flow plan)	Plan 8 - (minimum lake damage)	Plan 9 - (conservation plan)
	Operating plan (1977 prices)			
Headwaters lakes				
Winnibigoshish	$32,000	$48,000	$10,900	$14,800
Leech	151,600	162,500	76,800	51,000
Pokegama	38,000	53,500	5,100	29,900
Sandy	31,500	31,500	27,200	31,500
Pine River	22,900	22,900	15,300	22,900
Gull	142,700	142,700	87,300	142,700
Total headwaters lakes	418,700	461,100	222,600	292,800
Four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy)	253,100	295,500	120,000	127,200
Aitkin	278,600	277,700	417,600	283,100
Aitkin plus six headwaters lakes	697,300	738,800	640,200	575,900
Anoka	6,495,400	109,730,400	3,237,300	2,967,500
Total	7,931,500	110,469,200	3,877,500	3,538,400

Plan 7 was identical to plan 6.

Plan 10 - HEC program not capable of running the plan.

Evaluation

SAFHL's stage 2 results and ANCO's stage 3 results for the first four operating plans compare well, considering all the difficulties SAFHL had with the earlier HEC-5c program analysis. Generally speaking, ANCO results illustrate approximately 25 percent less damages at the six headwaters lakes and 8 percent less damage at Aitkin than do the SAFHL results. However, even more interesting is the fact that both the ANCO and SAFHL results show less damage than actually observed for the present operating plan. This difference between actual conditions and the computer-simulated present operating plan is probably due to the following main factors:

1. The difficulty in simulating actual conditions exactly.

2. The difficulty in assessing basin conditions during actual operations (erroneous gage readings, effects of wind and rain, etc.)

3. The inability of the operator to predict future conditions in advance.

4. ANCO and SAFHL operating runs used Lake Winnibigoshish desirable summer levels (9.0 to 9.5-foot stage) for the evaluated period of record, whereas actual Lake Winnibigoshish desirable summer levels before 1975 were 1 foot higher (at the 10.0 to 10.5-foot stage).

Plan 7 (hydropower) and plan 10 (Sandy Lake) were not studied using HEC-5. Plan 7 was considered identical to plan 6 (4,800-cfs low-flow plan) and the goals of this plan could not be met a great deal of the time by releases from the six headwaters lakes. Plan 10 involved a flood control operation specifically for Sandy Lake, which the HEC-5 program could not evaluate.

The above analysis shows that the best overall plans for individual areas are as follows:

Area	Best plan
Six headwaters lakes	Plan 8 - minimum lake damage
Aitkin area	Plan 3 - flood control
Anoka	Plan 6 - 4,800 cfs low flow
Six headwaters lakes plus Aitkin	Plan 9 - conservation plan

Although plan 1 (present conditions) does not appear as the best plan for any single area, it attempts to consider all interests and therefore benefits all areas without causing extreme hardships to any one specific area.

Also, it should be emphasized that the preceding table compares flood and loss of business damages for the six Mississippi River headwaters areas and Aitkin, with potential water supply benefits to the Twin Cities at Anoka. The table does not include numerical losses to wildlife or wild rice crops in the six headwaters lakes, nor does it include potential benefits to pollution abatement as discussed under "Low-Water Damage" in this appendix.

It is interesting to note that the present plan (plan 1) and the 1,600-cfs low-flow plan (plan 2) are almost equal in damages in the headwaters lakes (320,900 vs. 327,000). And although plan 8 is best for the six headwaters lakes ($222,600), it would greatly increase Aitkin average annual damages from $278,600 at present to $417,600. Operating for plan 3, flood control at Aitkin, would result in a similar hardship for the six headwaters lakes, causing annual damage there to rise from $320,900 to $586,800. The 4,800-cfs low flow plan (plan 6) would have significant potential water supply (if needed) benefits at Anoka, but to the detriment of the six headwaters lakes. Average annual damage in the six lakes could increase from $320,900 to $461,000, although Aitkin would receive a slight benefit from flood control.

The main problem with plan 6 is that this plan is not needed to meet estimated year 2015 low flow water supply requirements in the Twin Cities. The 1,600-cfs plan (plan 2) would suffice. The 4,800-cfs plan could be used in an attempt to avoid tertiary treatment costs for metropolitan area waste disposal. In fact, plan 6 could not meet this requirement at Anoka. Water shortages would occur at Anoka for 187 months (33 percent of the total period of 564 months of simulation) for the 4,800-cfs release attempt. Shortages would occur in months of every year between 1930 and 1976 except 1942, 1944, 1946, 1952, 1954, 1966, 1972, [illegible], and 1975.

Plan 5 (2,275-cfs minimum at Anoka) also [illegible] times during the 1930 to 1976 period. Shortages [illegible] out of 564 months, or almost 7 percent of the time. [illegible] would occur in the year 1930, 1932, 1933, 1934, [illegible] 1940, 1976.

According to the ANCO study, plan 2 (1,600-cfs [illegible] provide the required releases during the entire [illegible]

The conservation plan, in contrast, would [illegible] in the headwaters grouping (actually at Leech Lake [illegible] damages would decline from $320,900 to $29[illegible] would increase slightly from $278,600 to $28[illegible] at Anoka would increase by $227,400.

Summary

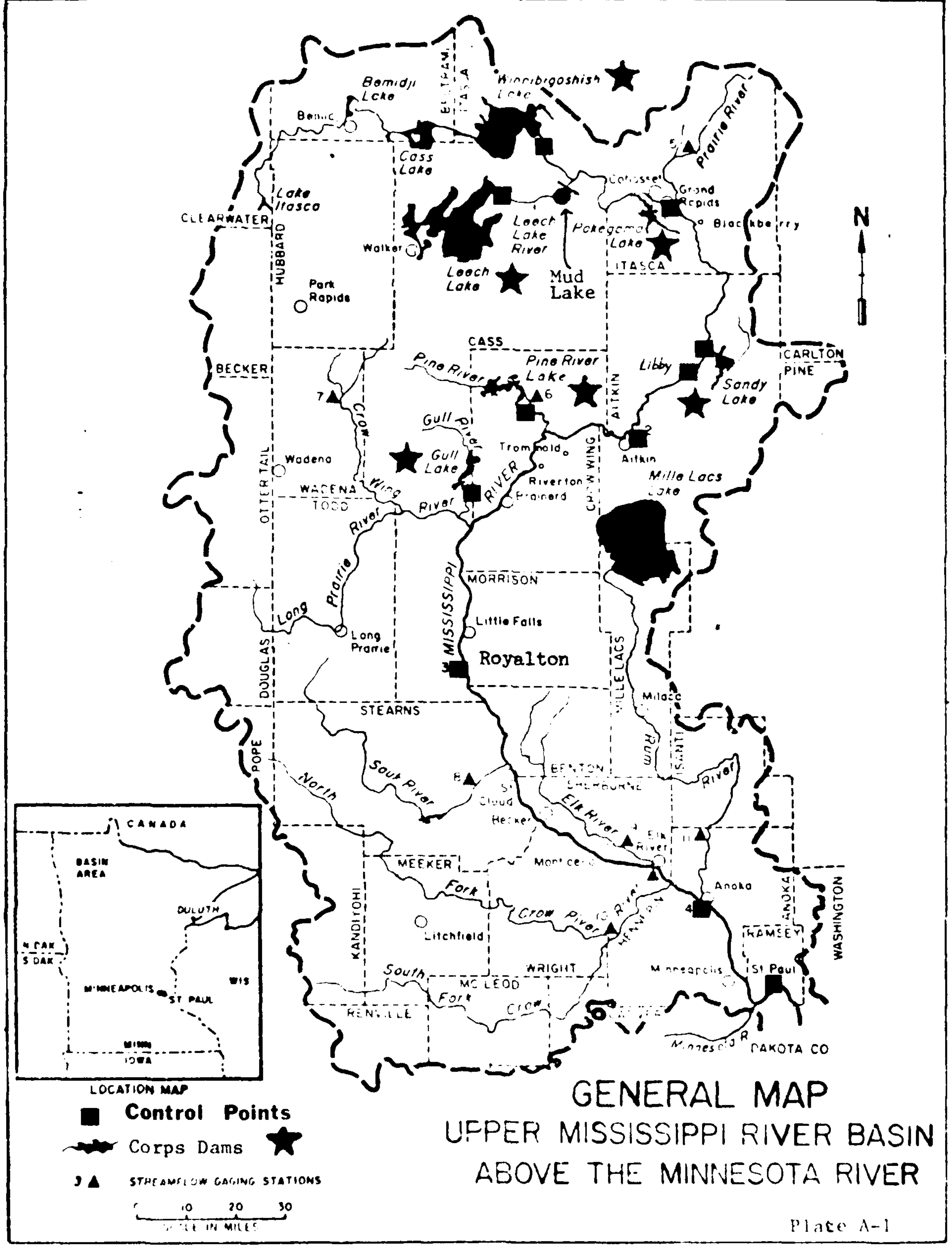
No benefit-cost ratio analysis is approp[illegible] ever, an analysis of upstream damages or potent[illegible] at Anoka provides a good comparison [illegible]

With regard to the tables on the preceding [illegible] and stage 3 summary analyses, it is clear [illegible] point that a change in operation could be [illegible] a 1,600-cfs minimum flow at Anoka at all times [illegible] sults show that 1,600-cfs could be maintained [illegible] 47-year period of record through supplemental [illegible] Leech, and Pokegama Lakes. Average annual [illegible] only $7,000 total; Aitkin would not be affected [illegible] (Twin Cities) for water supply would increase [illegible] over the current operation plan. However, [illegible] and political consequences of adopting the plan [illegible] are considered, the economic argument [illegible]

In summary, it would seem desirable to continue operating the six headwaters lakes much as they are under the present plan (plan 1) or a variation of the conservation plan (plan 9), which is within the limits of the present operating plan. The target levels proposed by the Department of Natural Resources for improving the fishery [illegible] Fish Lake and by the Leech Lake Tribe for wild rice [illegible] Leech Lake (plan 9) should be implemented in the operati[illegible] the next 5 years. If this operating plan is still a[illegible] that time, it should be formalized by means of a public [illegible].

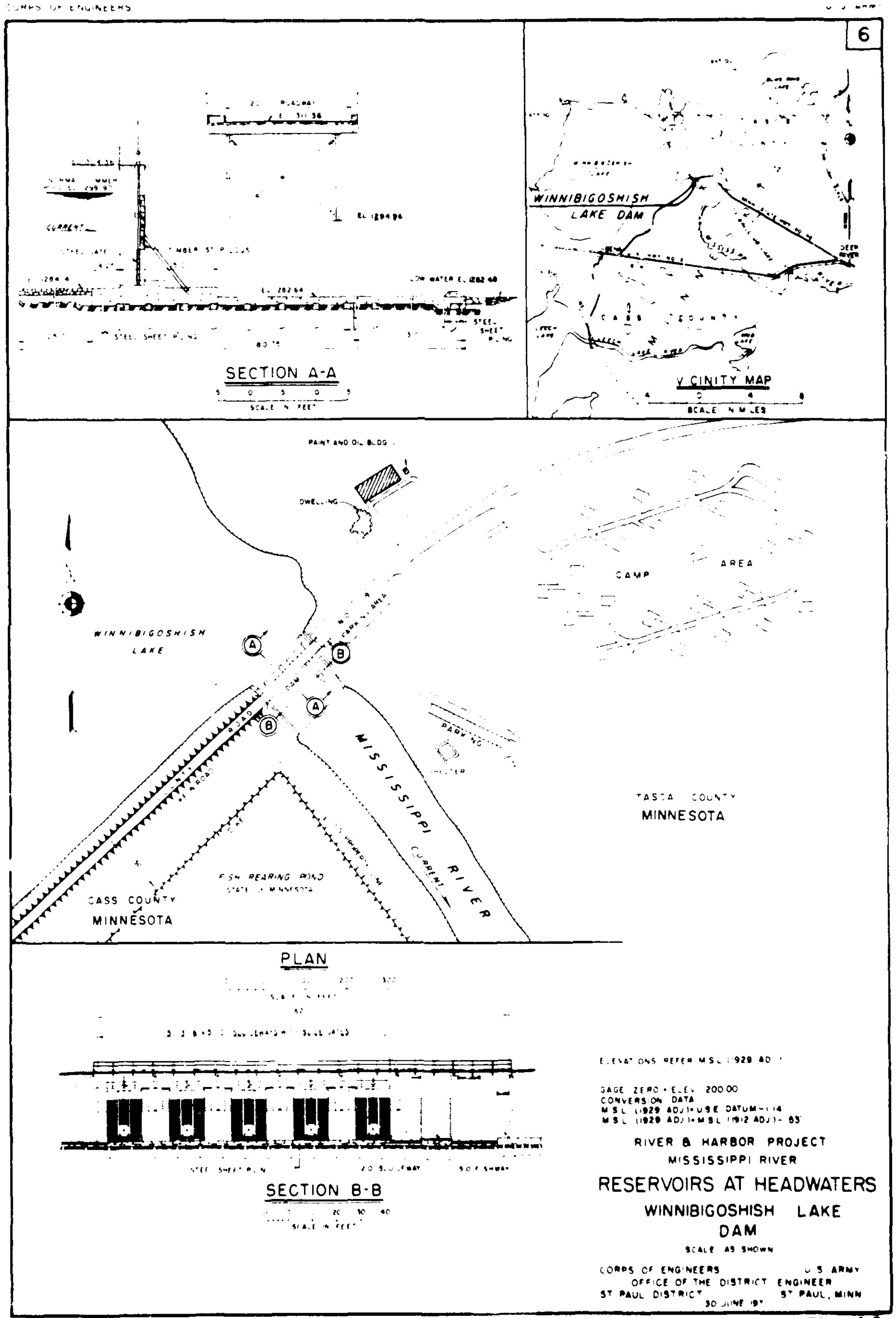
PLATE SUMMARY

Number	Item
A-1	General map.
A-2 - A-7	Reservoirs at headwaters - six site location maps.
A-8	Original area curves.
A-9 - A-14	Area-capacity curves (six).
A-15 - A-16	Tentative guide curves.
A-17	Aitkin rating curve.
A-18 - A-23	Elevation-damage curves - six headwaters lakes.
A-24 - A-27	Aitkin area damages.
A-28	Aitkin agricultural area flooded.
A-29 - A-34	Damage-frequency curves for six headwaters lakes.
A-35	Average annual damage - urban Aitkin.
A-36	Average annual damage - Aitkin area rural property.
A-37	Average annual area flooded - Aitkin agricultural.
A-38 - A-60	Plan 1, time series data plots and data tables.



GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER

Plate A-1


6
SECTION A-A
SCALE IN FEET
STEEL SHEET PILING
LOW WATER EL 1282.40
CURRENT
VICINITY MAP
SCALE IN MILES
WINNIBIGOSHISH LAKE DAM
DEER RIVER
CASS COUNTY
PAINT AND OIL BLDG.
DWELLING
CAMP AREA
WINNIBIGOSHISH LAKE
MISSISSIPPI RIVER
CURRENT
PARKING
FISH REARING POND
STATE OF MINNESOTA
ITASCA COUNTY
MINNESOTA
CASS COUNTY
MINNESOTA
PLAN
SECTION B-B
SCALE IN FEET
ELEVATIONS REFER M.S.L. 1929 ADJ.
GAGE ZERO = ELEV. 1200.00
CONVERSION DATA
M.S.L. (1929 ADJ.) = U.S.E. DATUM - 1.14
M.S.L. (1929 ADJ.) = M.S.L. (1912 ADJ.) - .65
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
WINNIBIGOSHISH LAKE
DAM
SCALE AS SHOWN
CORPS OF ENGINEERS
U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT
ST. PAUL, MINN.

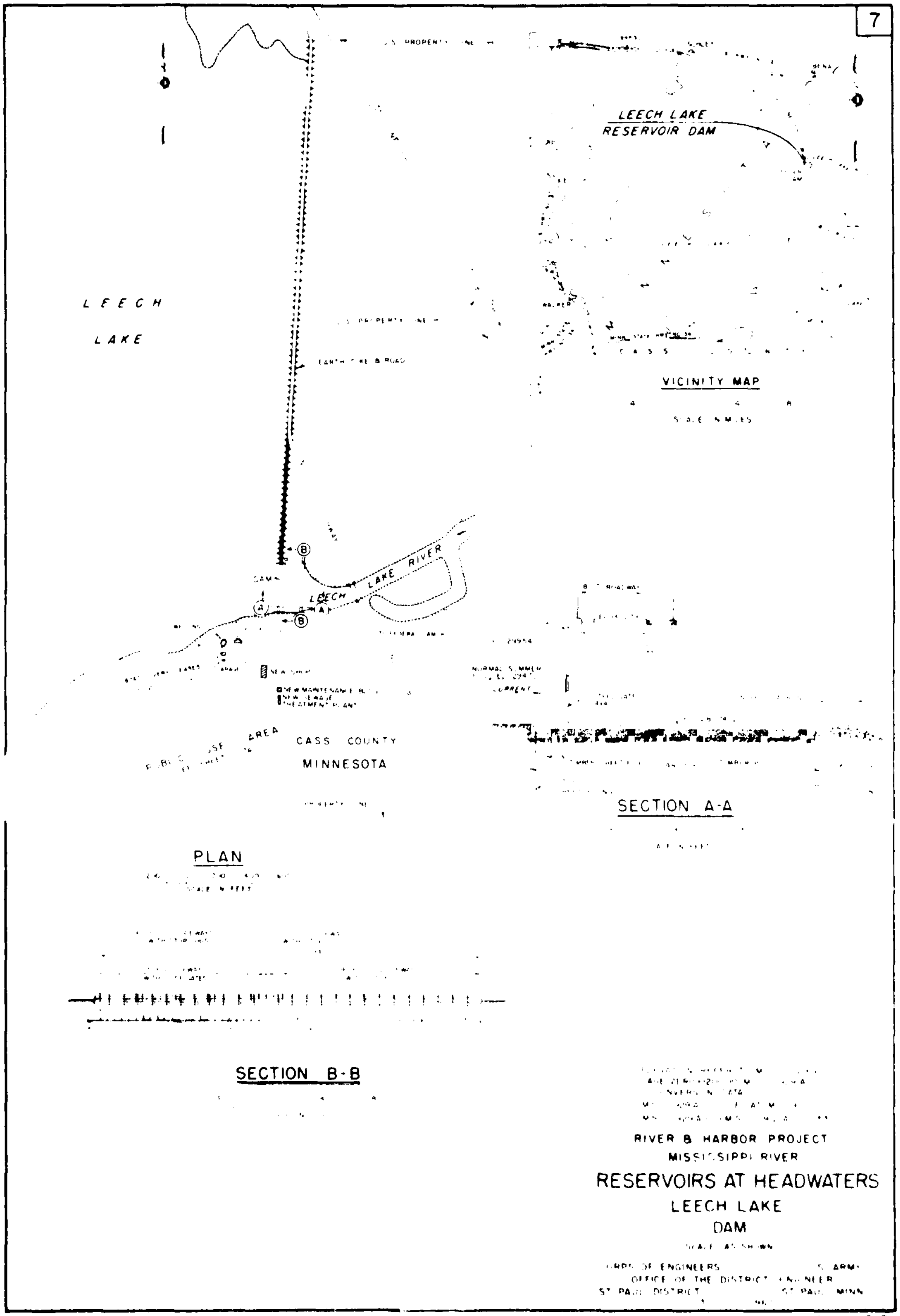
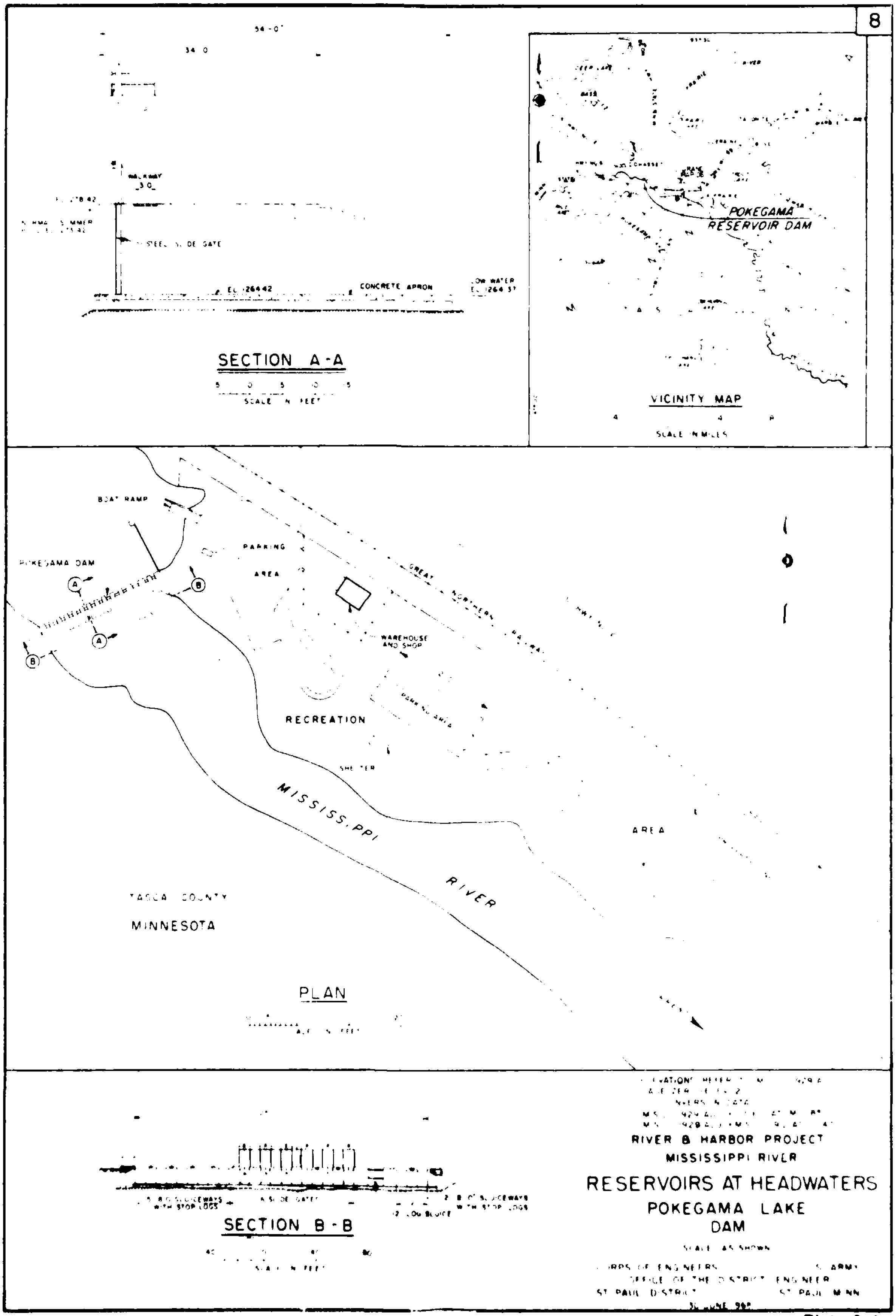

7
LEECH LAKE
RESERVOIR DAM
VICINITY MAP
LEECH
LAKE
LEECH LAKE RIVER
CASS COUNTY
MINNESOTA
PLAN
SECTION A-A
SECTION B-B
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
LEECH LAKE
DAM

Plate A-3


8
SECTION A-A
STEEL SLIDE GATE
CONCRETE APRON
LOW WATER
EL. 1264.42
VICINITY MAP
POKEGAMA RESERVOIR DAM
BOAT RAMP
POKEGAMA DAM
PARKING AREA
WAREHOUSE AND SHOP
RECREATION
SHELTER
AREA
MISSISSIPPI RIVER
GREAT NORTHERN RAILWAY
MINNESOTA
PLAN
SECTION B-B
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
POKEGAMA LAKE
DAM
SCALE AS SHOWN
ST. PAUL DISTRICT
ST. PAUL, MINN.

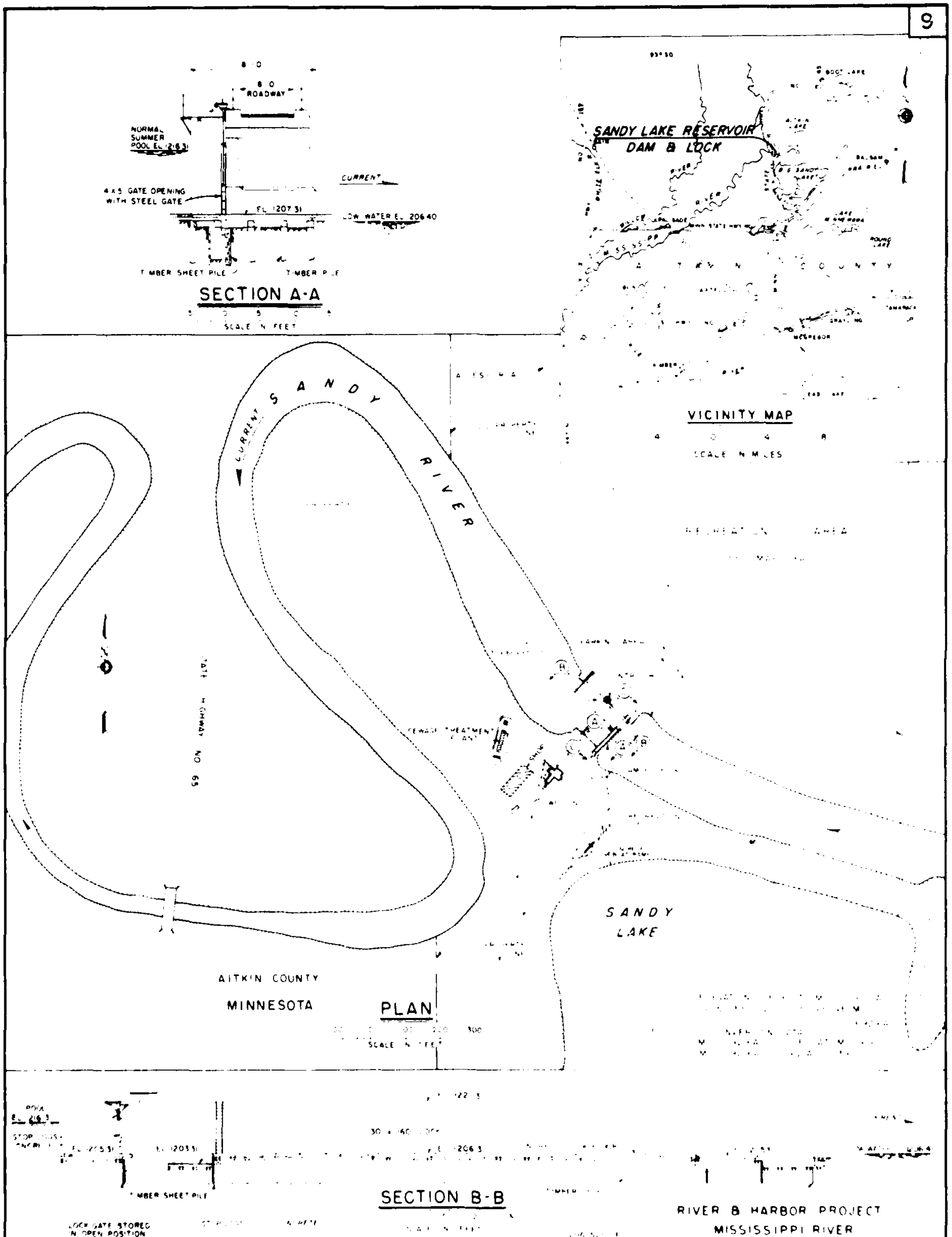
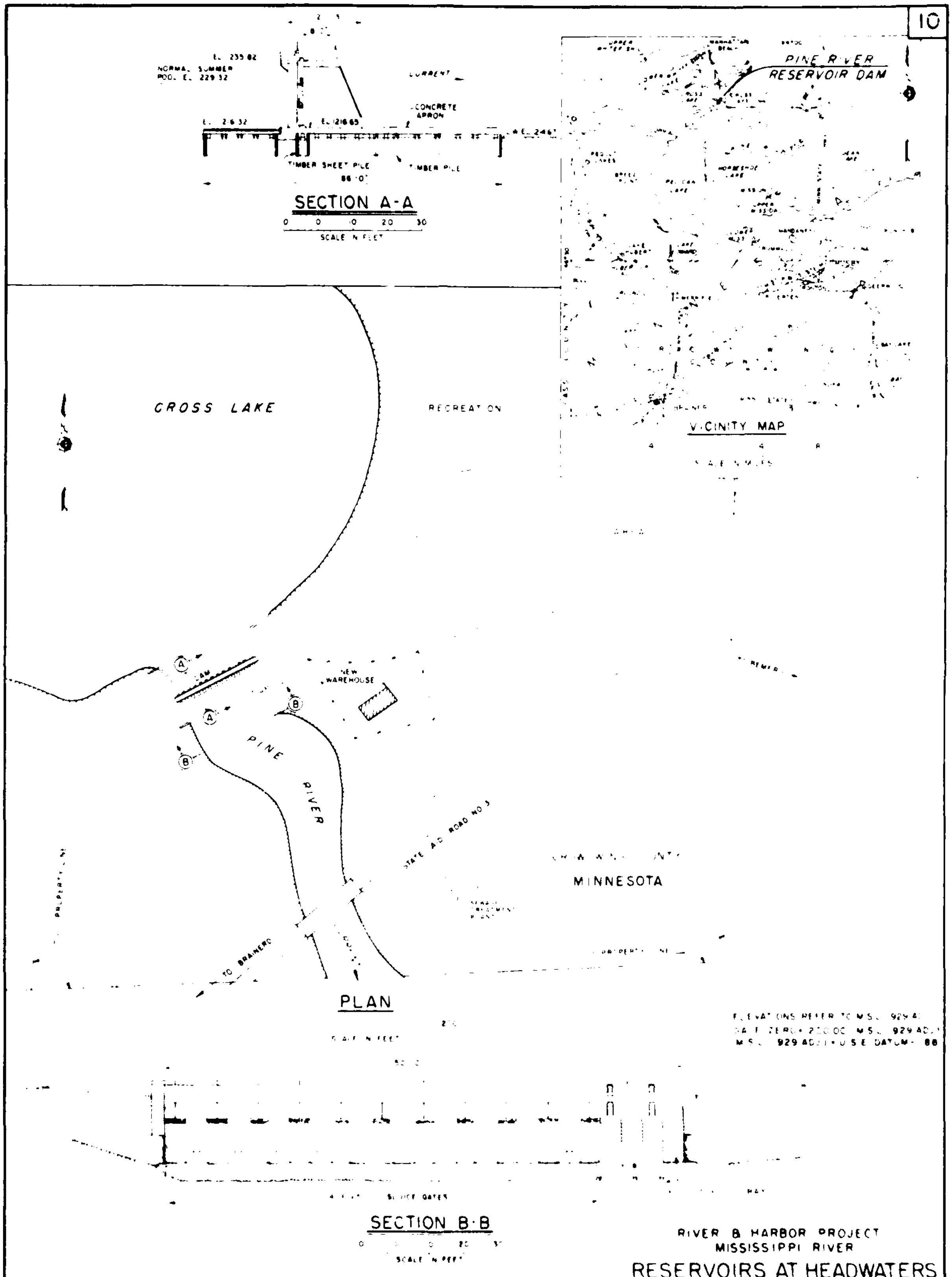

9
SECTION A-A
SCALE IN FEET
NORMAL SUMMER POOL EL. 1216.3
ROADWAY
CURRENT
4 X 5 GATE OPENING WITH STEEL GATE
EL. 1207.3
LOW WATER EL. 1206.40
TIMBER SHEET PILE
TIMBER PILE
SANDY LAKE RESERVOIR DAM & LOCK
VICINITY MAP
SCALE IN MILES
SANDY RIVER
CURRENT
STATE HIGHWAY NO. 65
SANDY LAKE
AITKIN COUNTY
MINNESOTA
PLAN
SCALE IN FEET
SECTION B-B
SECTION C-C
LOCK GATE STORED IN OPEN POSITION
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
SANDY LAKE
DAM & LOCK

Plate A-5



RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
PINE RIVER LAKE
DAM

SCALE AS SHOWN
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST PAUL DISTRICT ST PAUL MINN
30 JUNE 1969

Plate A-6

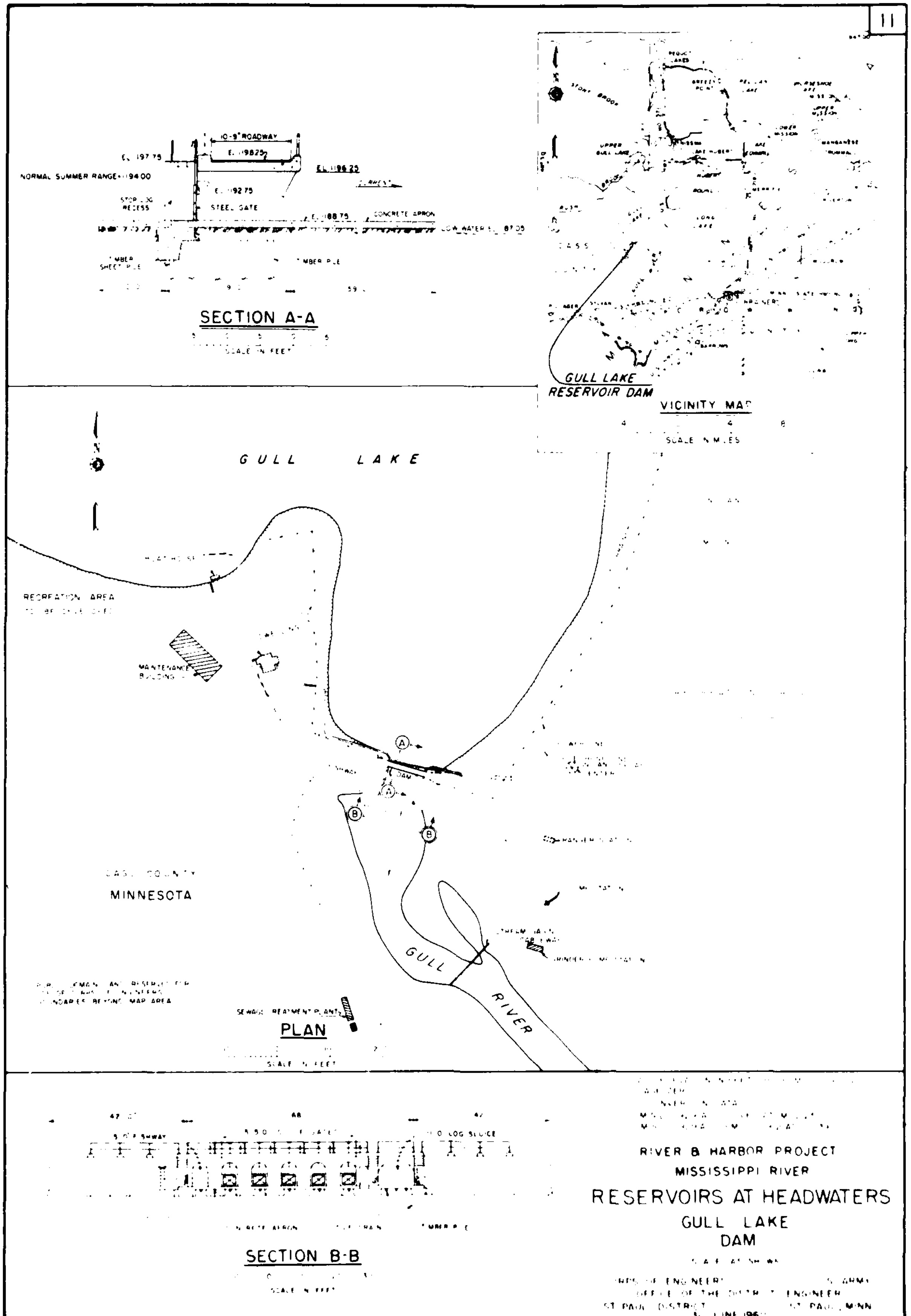

11
SECTION A-A
SCALE IN FEET
10'-9" ROADWAY
EL. 197.75
EL. 198.25
EL. 196.25
NORMAL SUMMER RANGE 194.00
EL. 192.75
STEEL GATE
STOP LOG RECESS
EL. 188.75
CONCRETE APRON
LOW WATER EL. 187.05
TIMBER SHEET PILE
TIMBER PILE
GULL LAKE RESERVOIR DAM
VICINITY MAP
SCALE IN MILES
GULL LAKE
RECREATION AREA
MAINTENANCE BUILDING
DAM
CASS COUNTY
MINNESOTA
GULL RIVER
SEWAGE TREATMENT PLANT
PLAN
SCALE IN FEET
SECTION B-B
SCALE IN FEET
LOG SLUICE
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
GULL LAKE
DAM
ST. PAUL DISTRICT
ST. PAUL, MINN.
JUNE 196

Plate A-7

MISSISSIPPI RIVER HEADWATER LAKES
ORIGINAL SURFACE AREA CURVES
(RETRACED FROM JULY 1945 CURVES)

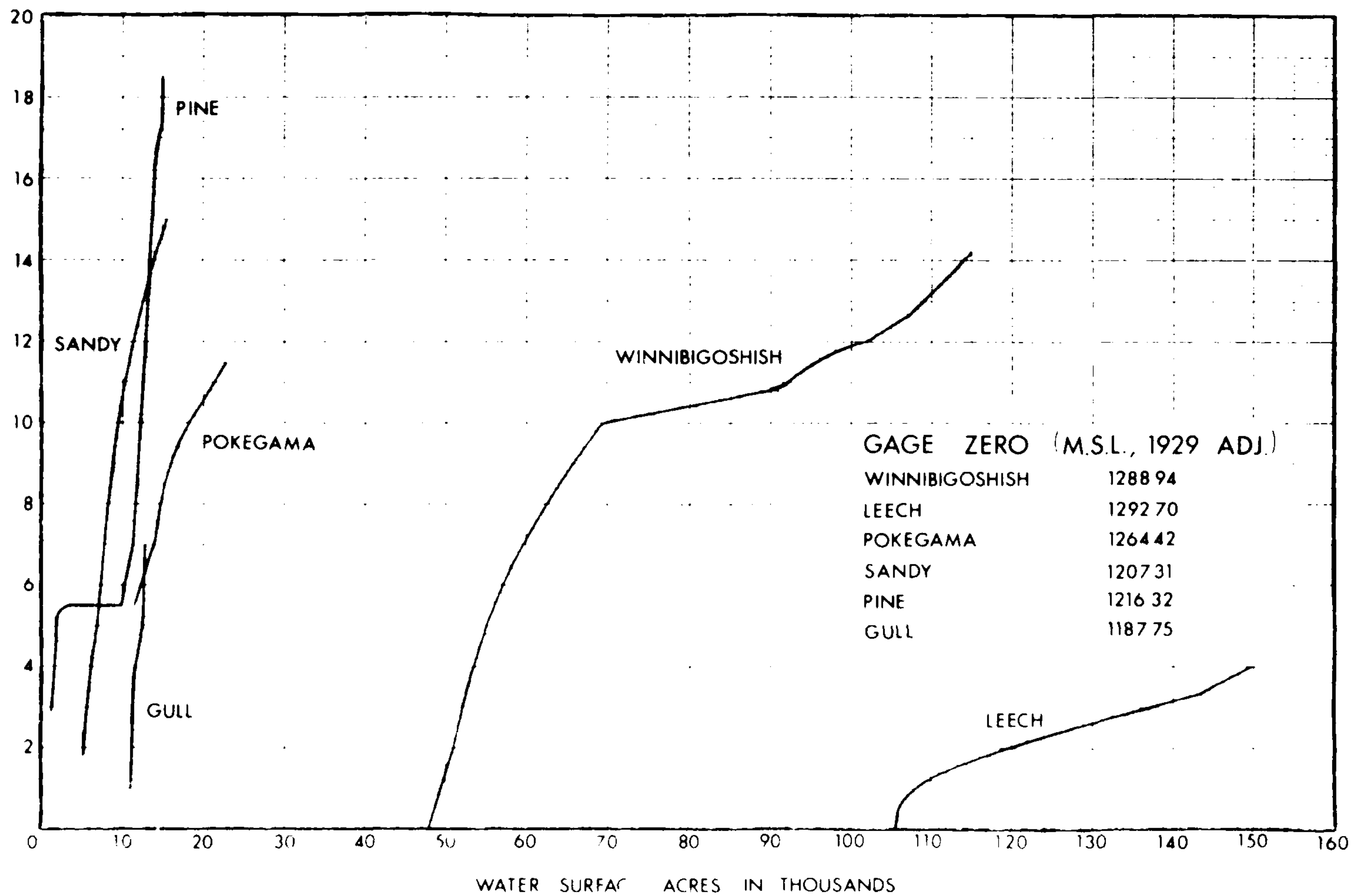
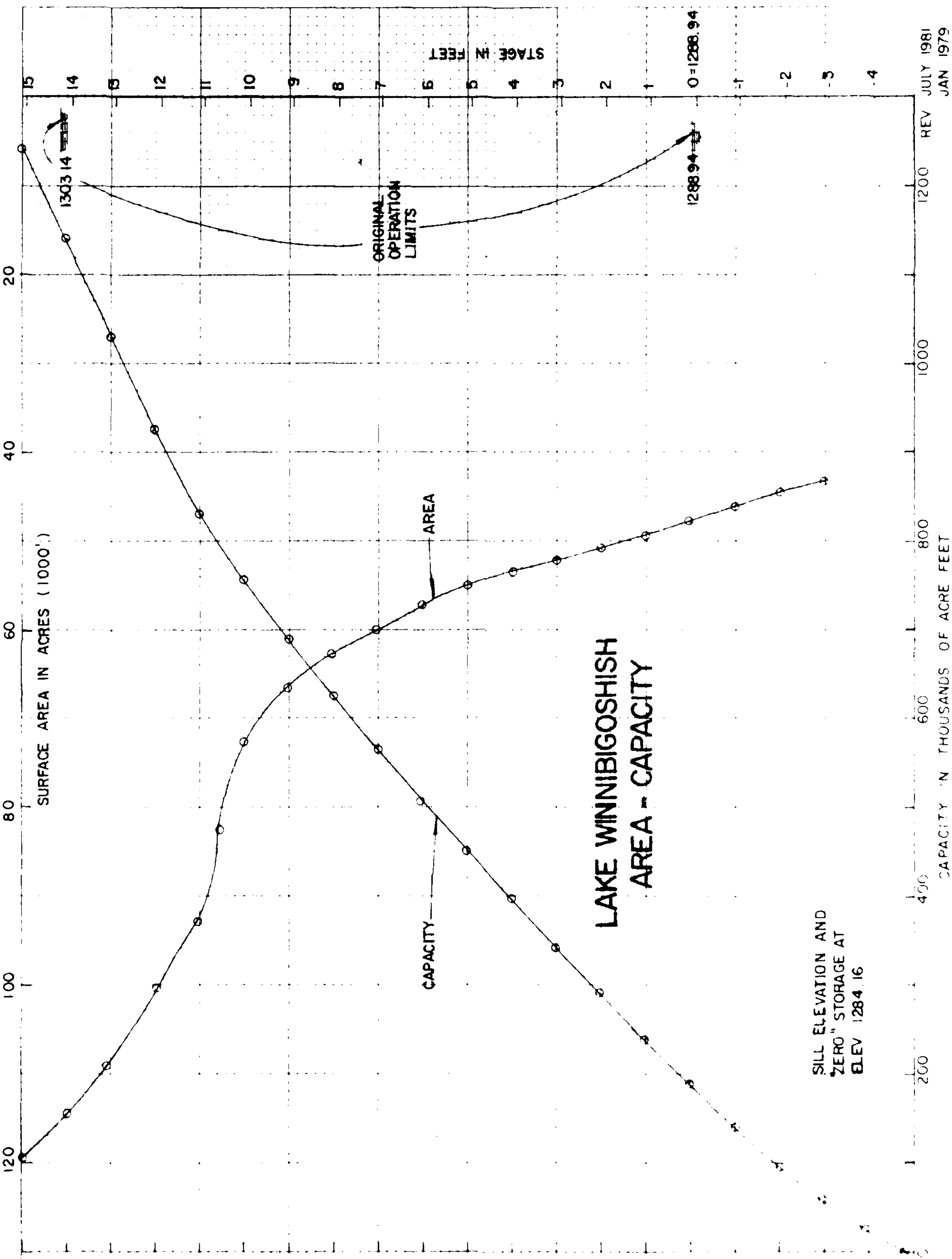


Plate A-8


LAKE WINNIBIGOSHISH
AREA - CAPACITY
SURFACE AREA IN ACRES (1000')
CAPACITY IN THOUSANDS OF ACRE FEET
ELEVATION IN FEET ABOVE M S L (1929 ADJ)
STAGE IN FEET
AREA
CAPACITY
ORIGINAL OPERATION LIMITS
1303.14
1288.94
0=1288.94
SILL ELEVATION AND "ZERO" STORAGE AT ELEV 1284.16
REV JULY 1981
JAN 1979

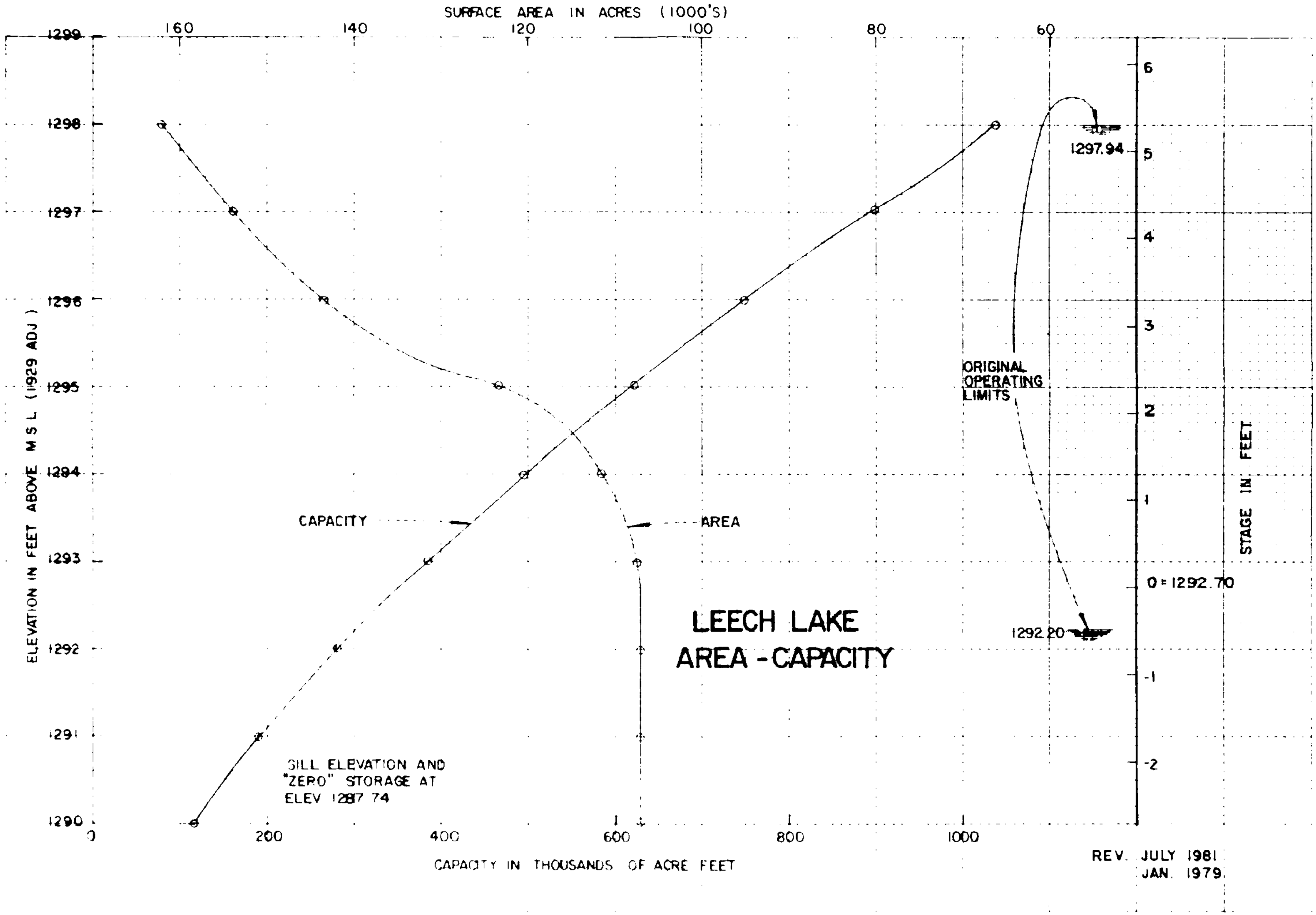
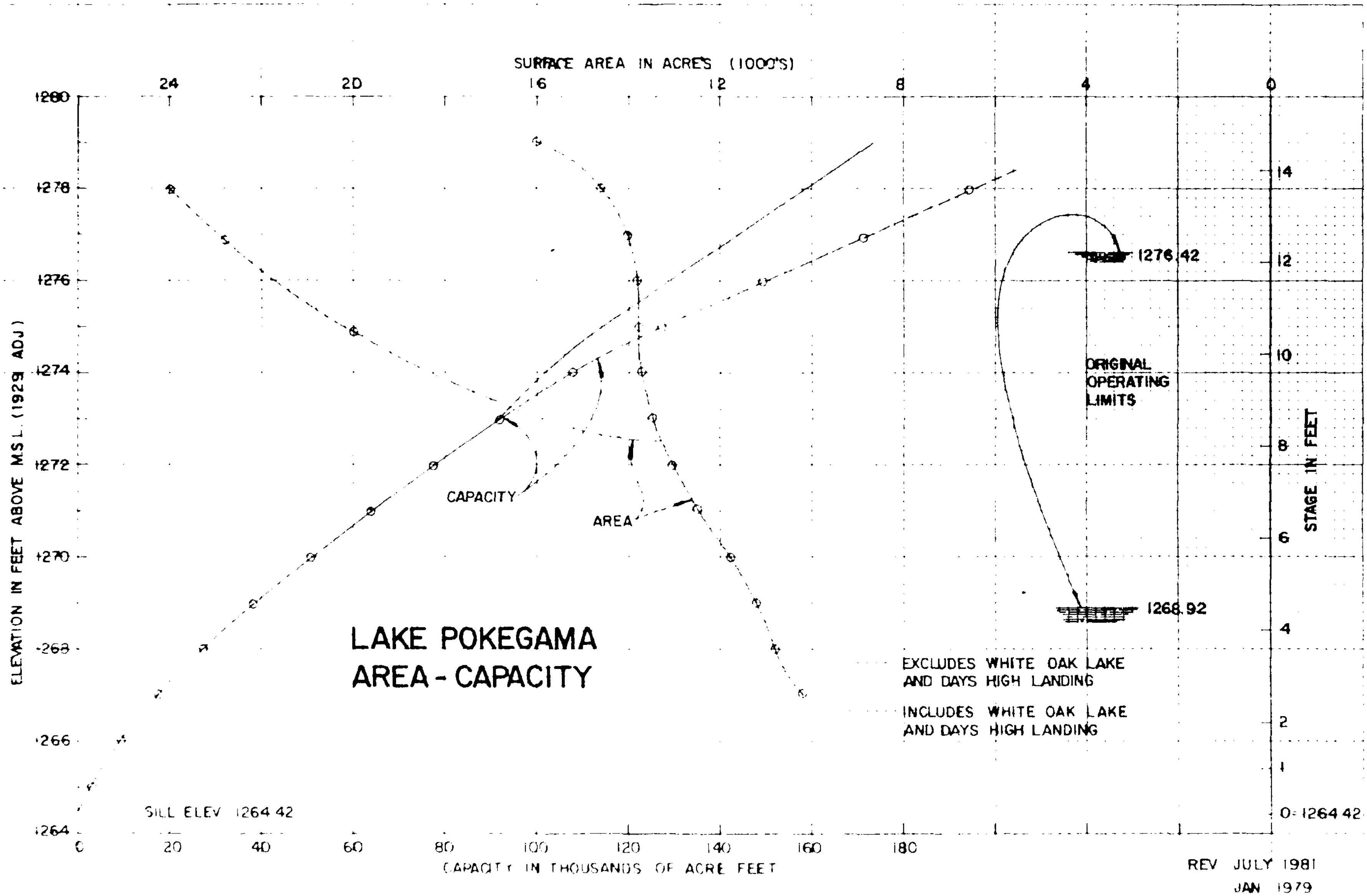
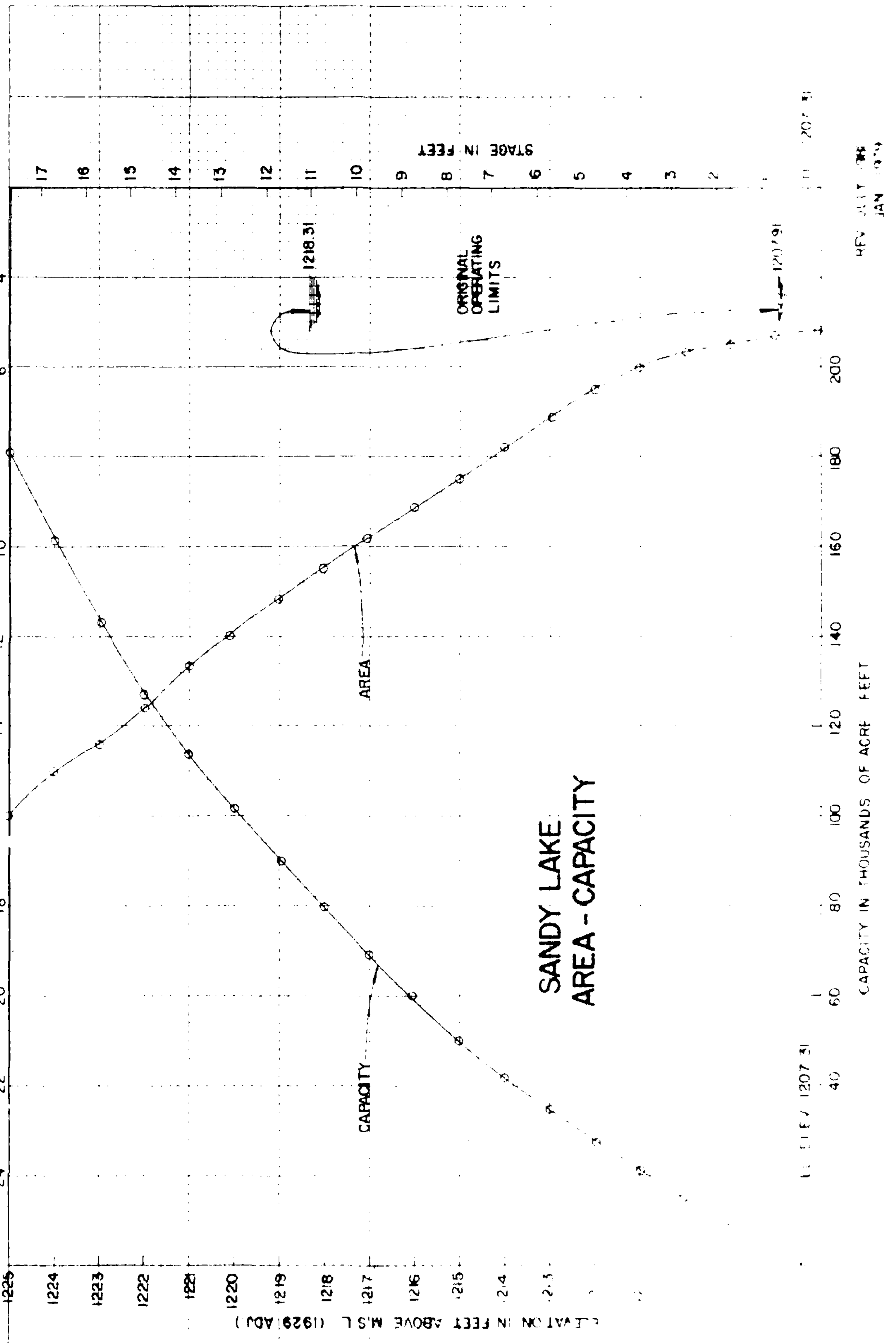

SURFACE AREA IN ACRES (1000'S)
160
140
120
100
80
60
ELEVATION IN FEET ABOVE M S L (1929 ADJ)
1299
1298
1297
1296
1295
1294
1293
1292
1291
1290
1297.94
ORIGINAL OPERATING LIMITS
1292.20
0 = 1292.70
STAGE IN FEET
6
5
4
3
2
1
-1
-2
CAPACITY
AREA
LEECH LAKE
AREA - CAPACITY
SILL ELEVATION AND "ZERO" STORAGE AT ELEV 1287.74
0
200
400
600
800
1000
CAPACITY IN THOUSANDS OF ACRE FEET
REV. JULY 1981
JAN. 1979

PLATE A-10

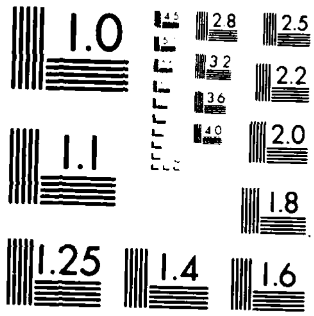

LAKE POKEGAMA
AREA - CAPACITY
SURFACE AREA IN ACRES (1000'S)
24
20
16
12
8
4
0
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ)
1280
1278
1276
1274
1272
1270
1268
1266
1264
CAPACITY IN THOUSANDS OF ACRE FEET
0
20
40
60
80
100
120
140
160
180
STAGE IN FEET
14
12
10
8
6
4
2
1
0=1264.42
CAPACITY
AREA
ORIGINAL
OPERATING
LIMITS
1276.42
1268.92
SILL ELEV 1264.42
EXCLUDES WHITE OAK LAKE
AND DAYS HIGH LANDING
INCLUDES WHITE OAK LAKE
AND DAYS HIGH LANDING
REV JULY 1981
JAN 1979

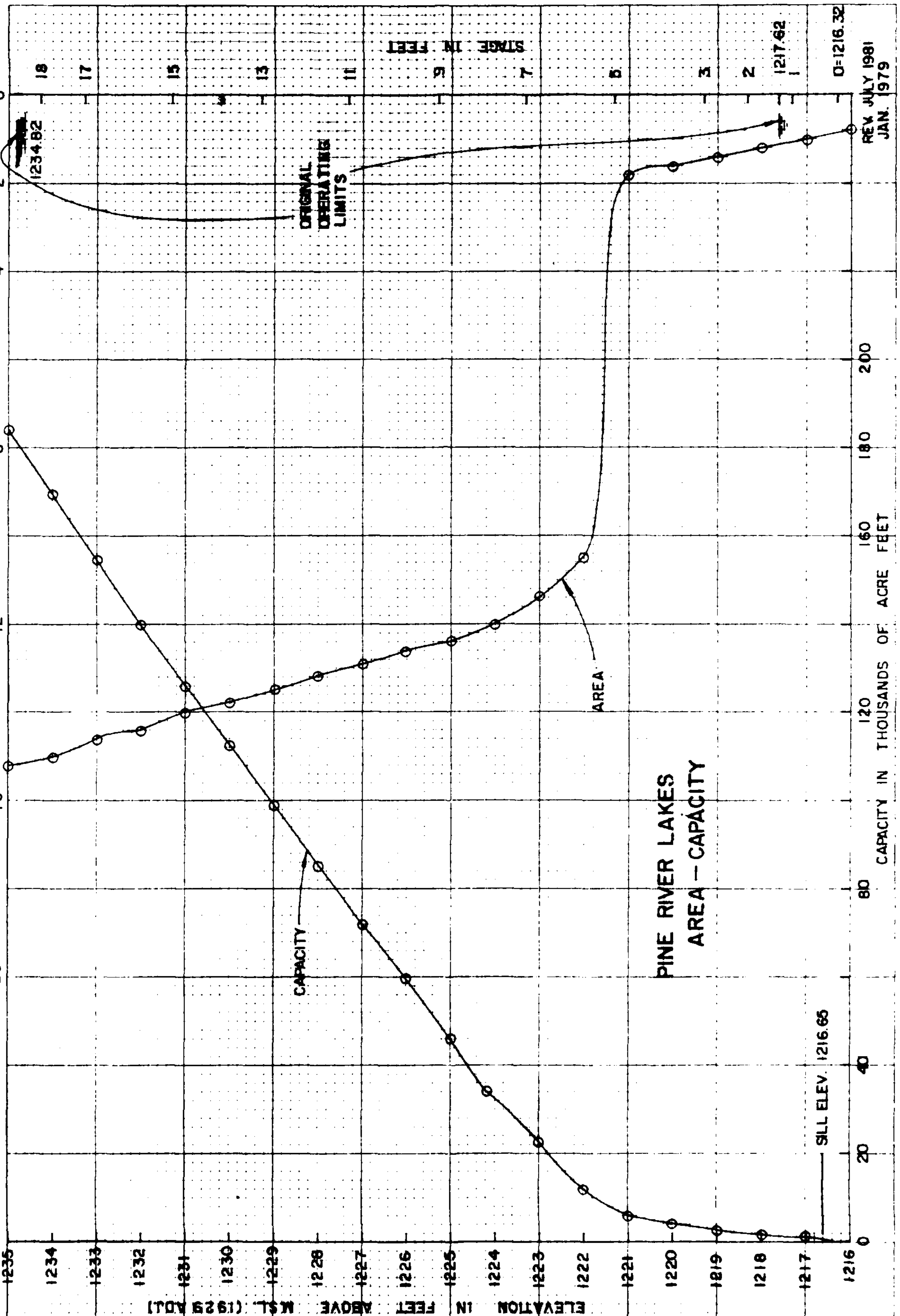

SANDY LAKE
AREA - CAPACITY
SURFACE AREA IN ACRES (1000'S)
CAPACITY IN THOUSANDS OF ACRE FEET
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ)
STAGE IN FEET
AREA
CAPACITY
ORIGINAL OPERATING LIMITS
1218.31
1207.31

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82

2/8

UNCLASSIFIED F/G 13/2 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0


PINE RIVER LAKES
AREA — CAPACITY
SURFACE AREA IN ACRE'S (1000'S)
CAPACITY IN THOUSANDS OF ACRE FEET
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)
STAGE IN FEET
AREA
CAPACITY
ORIGINAL OPERATING LIMITS
1234.82
1217.62
0=1216.32
SILL ELEV. 1216.65
REV. JULY 1981
JAN. 1979

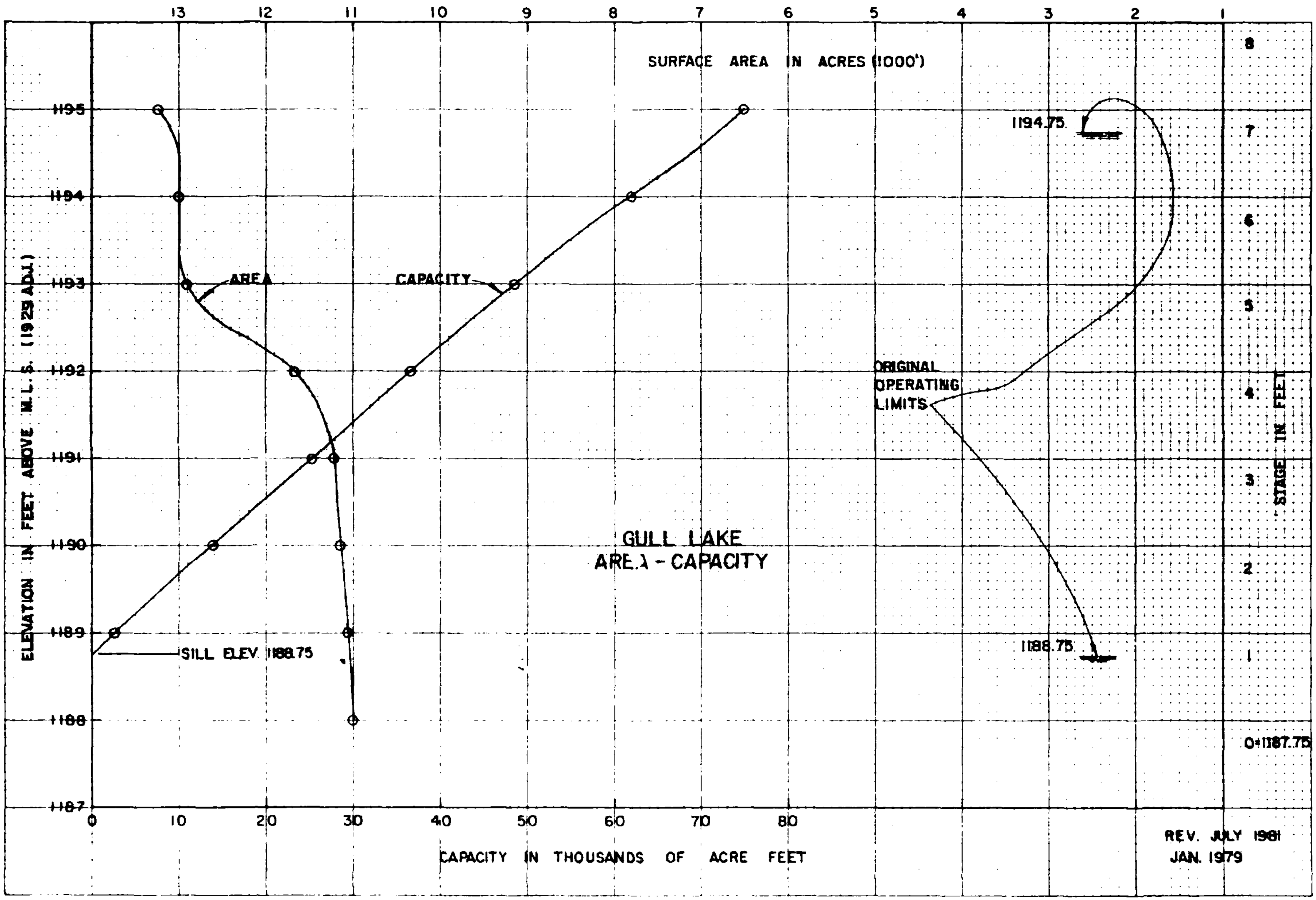
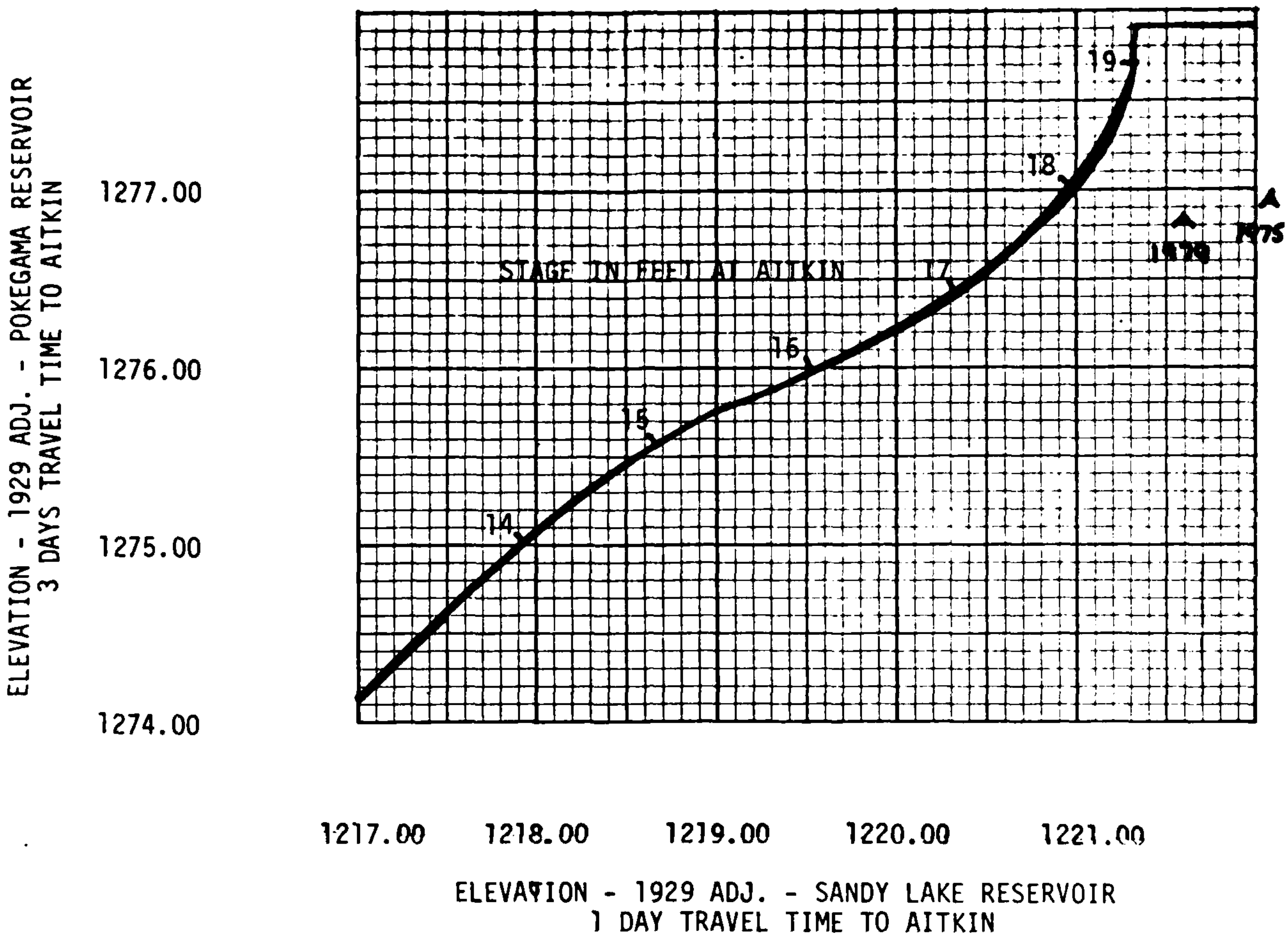

GULL LAKE
AREA - CAPACITY
SURFACE AREA IN ACRES (1000')
CAPACITY IN THOUSANDS OF ACRE FEET
ELEVATION IN FEET ABOVE M.L.S. (1929 ADJ.)
STAGE IN FEET
AREA
CAPACITY
SILL ELEV. 1188.75
ORIGINAL OPERATING LIMITS
1194.75
1188.75
0=1187.75
REV. JULY 1981
JAN. 1979

PLATE A-14

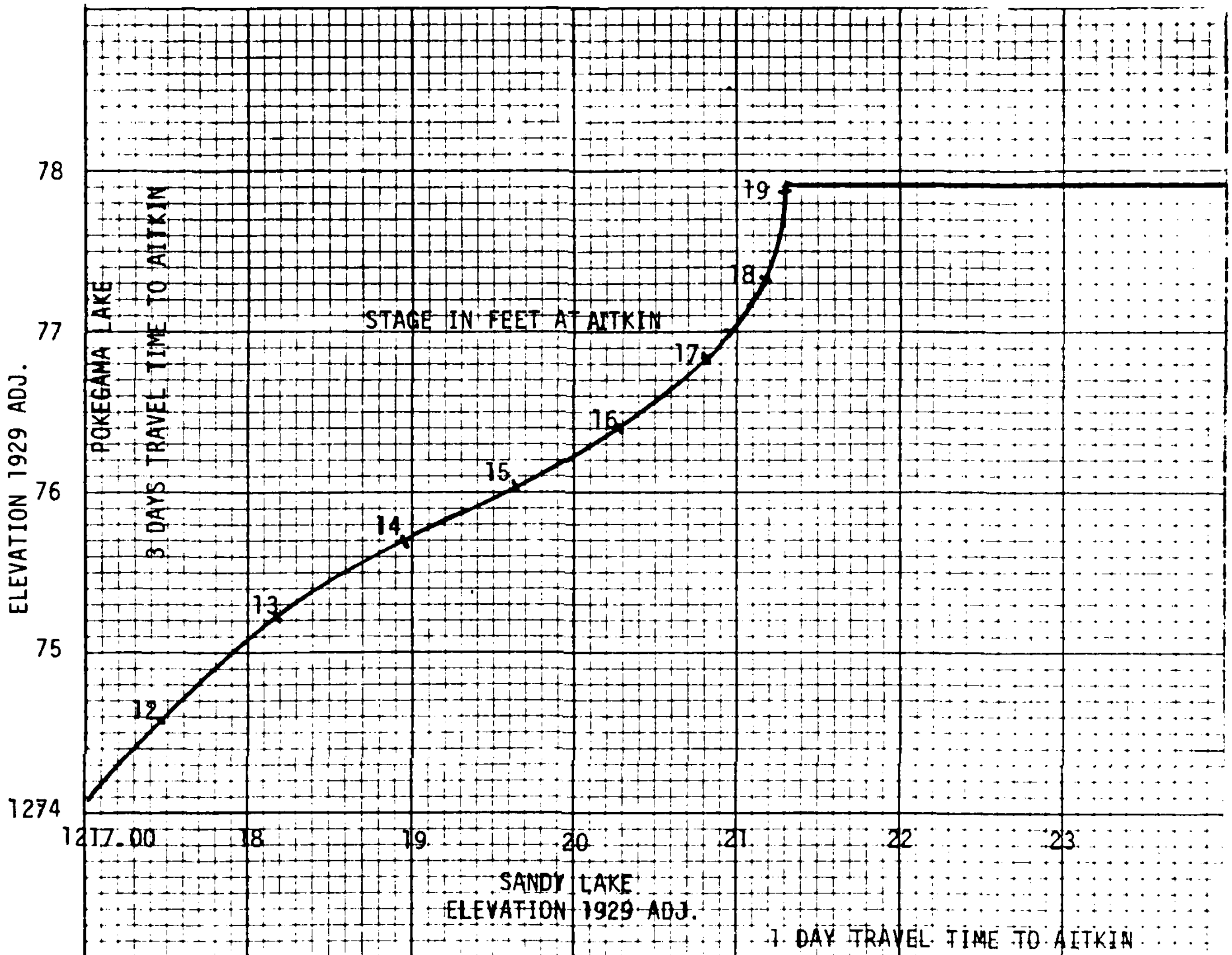


NOTE:

Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAMS AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL
TENTATIVE GUIDE CURVE
SPRING FLOODS (MAR -15 MAY)

Plate A-15

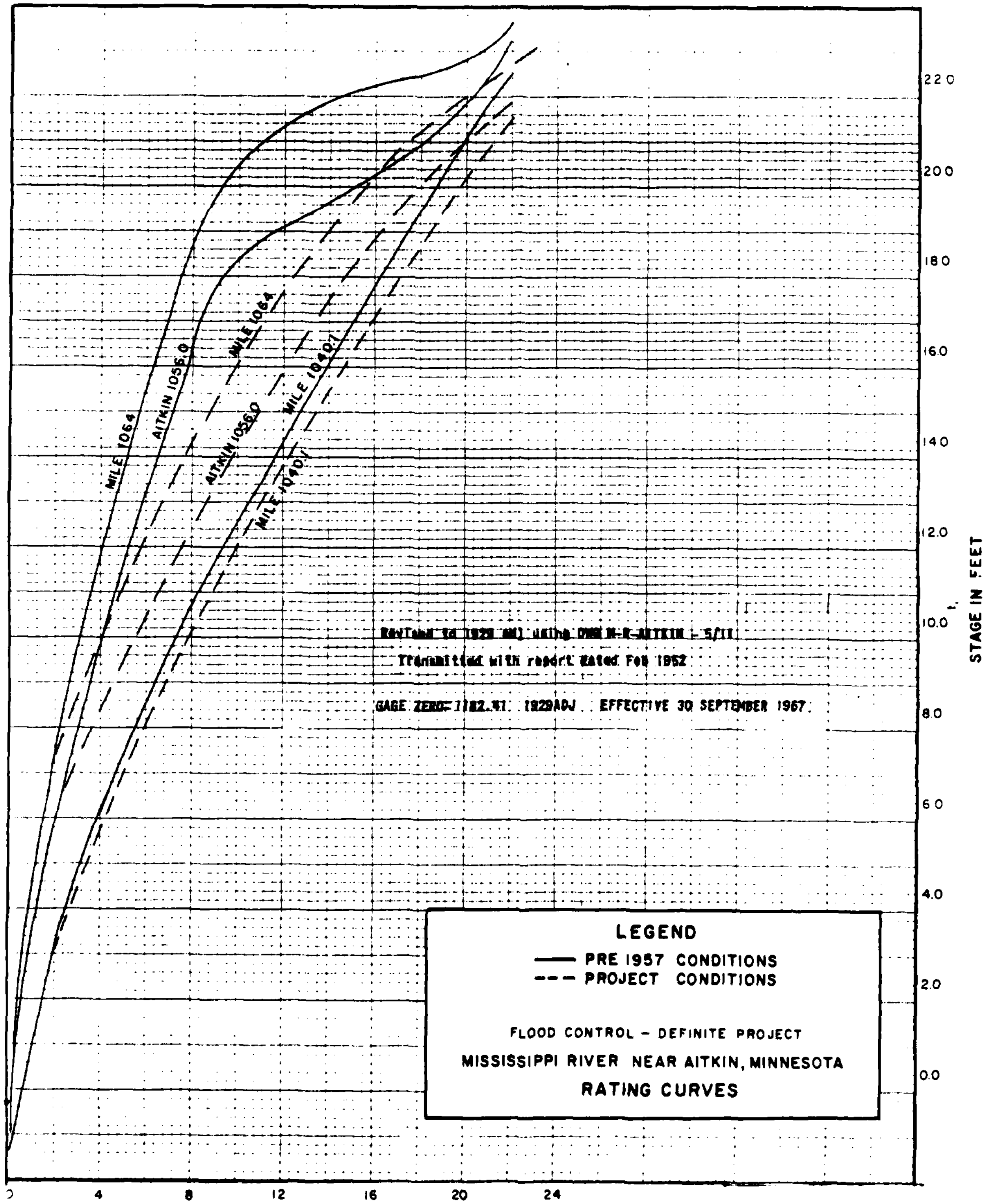


NOTE

Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAM AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL
TENTATIVE GUIDE CURVE
SUMMER FLOODS (15 May-Sept)

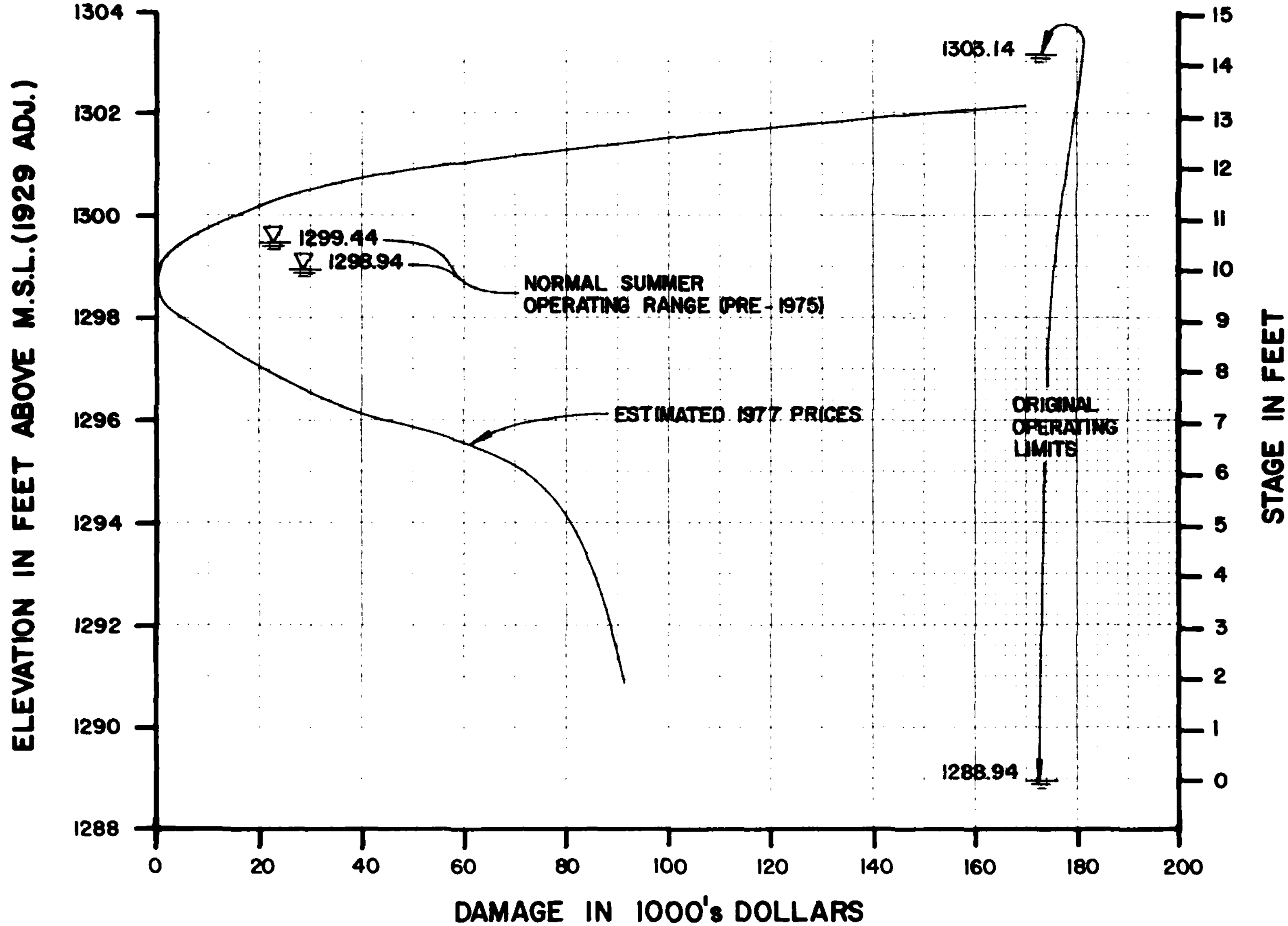
FEB 28 1977



TOTAL DISCHARGE BELOW PINE KNOLL
DIVERSION CHANNEL

PLATE A-17

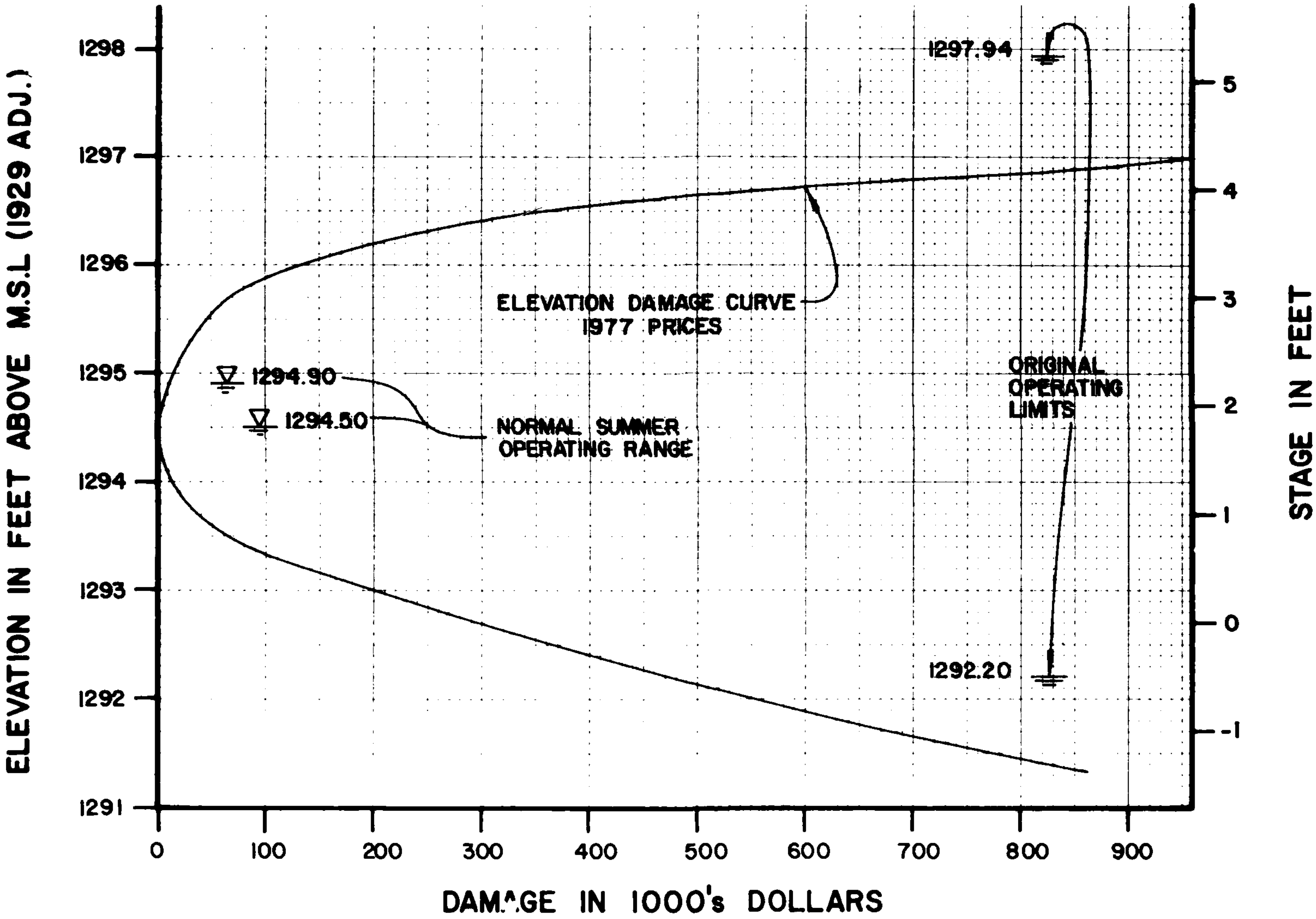
WINNIBIGOSHISH LAKE
ELEVATION DAMAGE CURVE



APRIL 1978

PLATE A-18

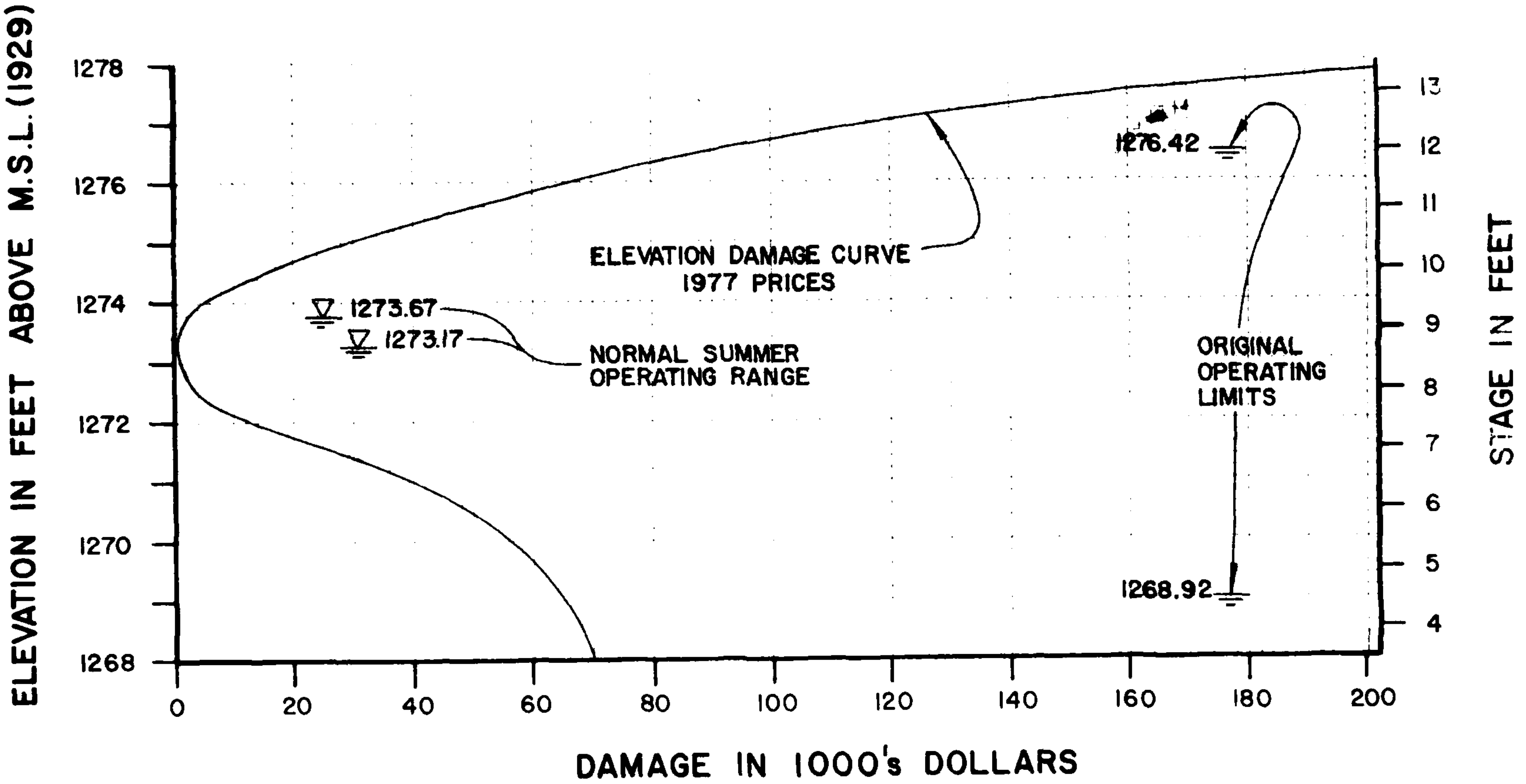
LEECH LAKE
ELEVATION DAMAGE CURVE



APRIL 1978

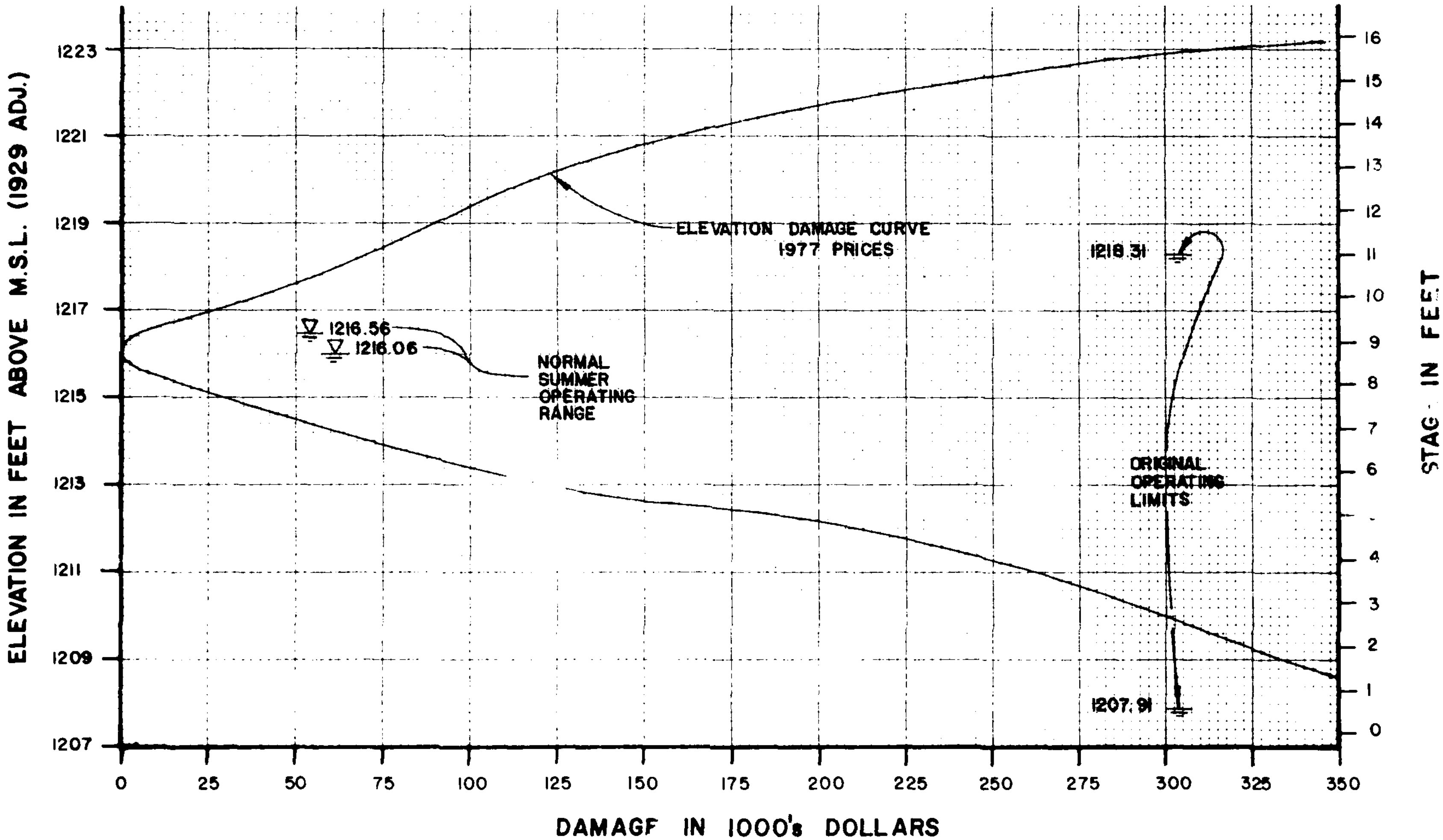
PLATE A-19

POKEGAMA LAKE
ELEVATION DAMAGE CURVE



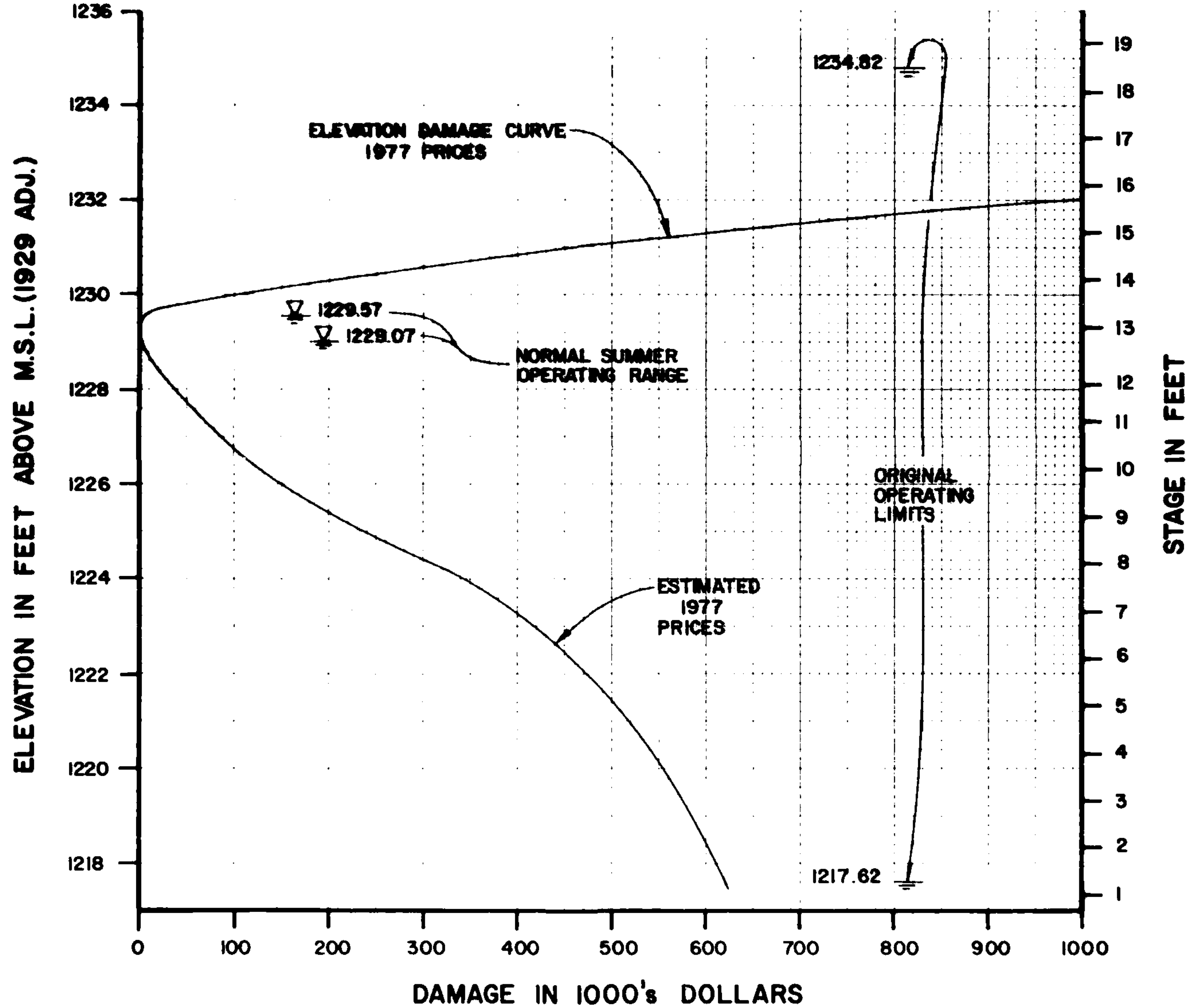
APRIL 1978

SANDY LAKE
ELEVATION DAMAGE CURVE



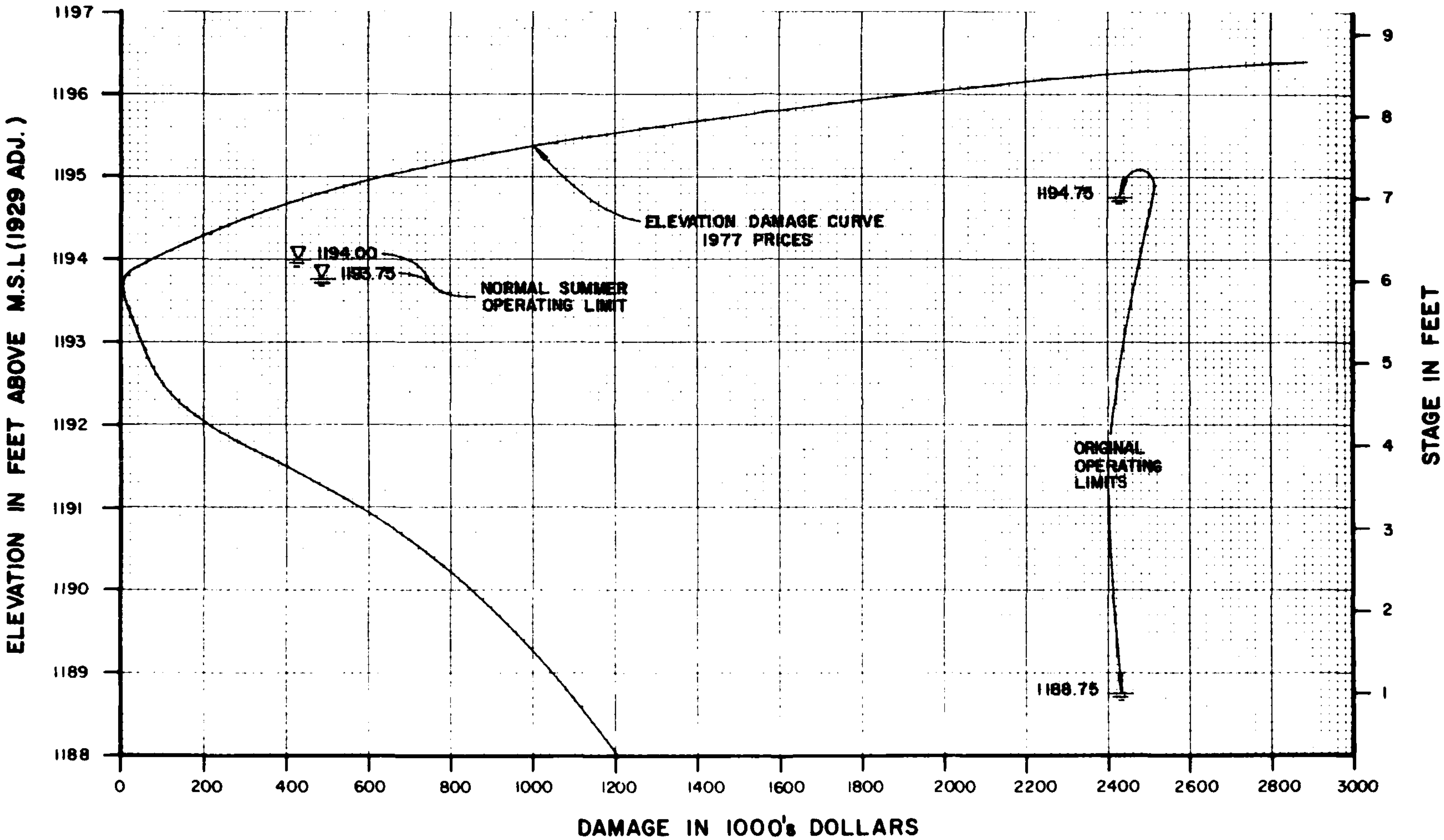
APRIL 1978

PINE LAKE
ELEVATION DAMAGE CURVE

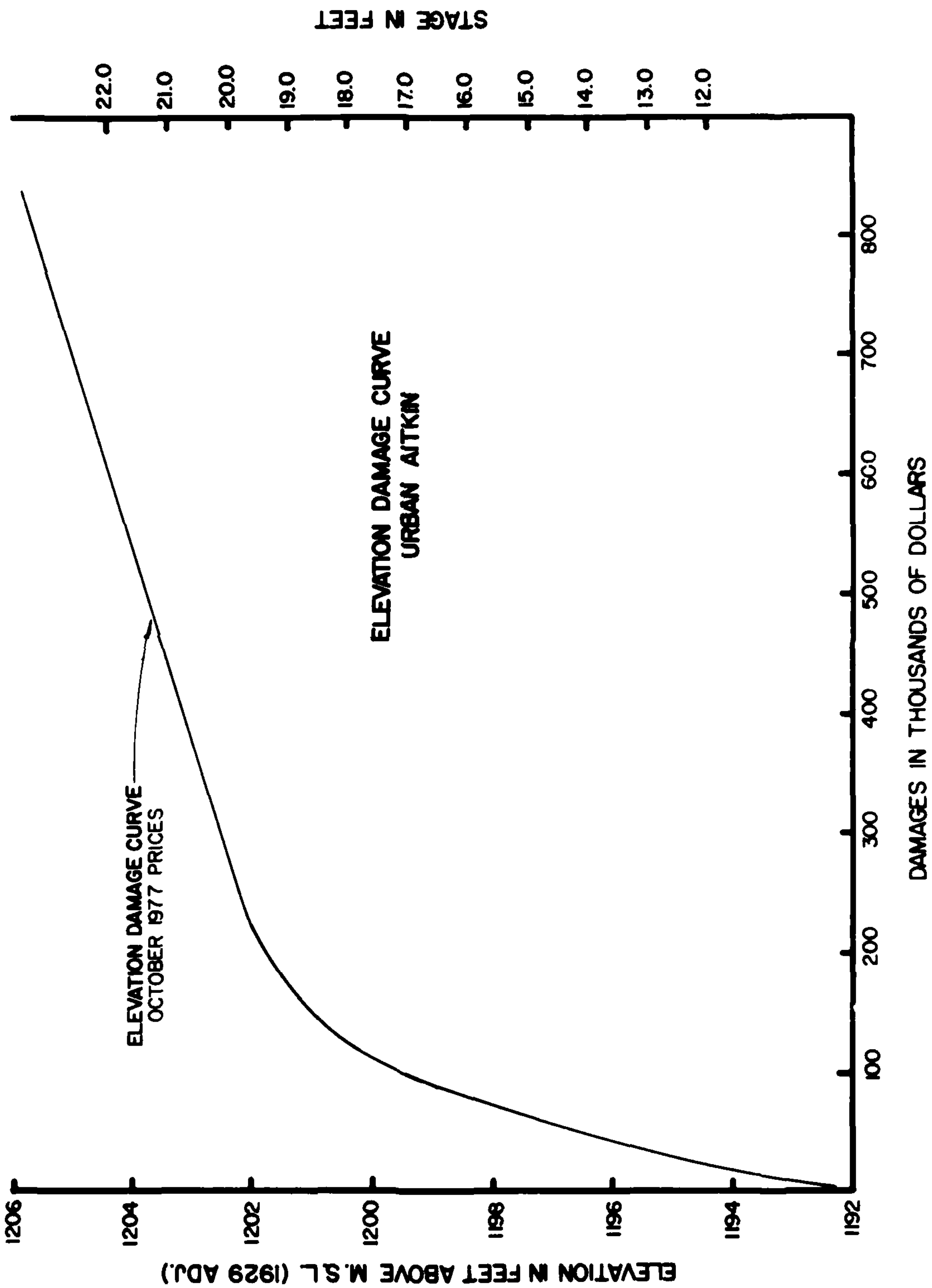


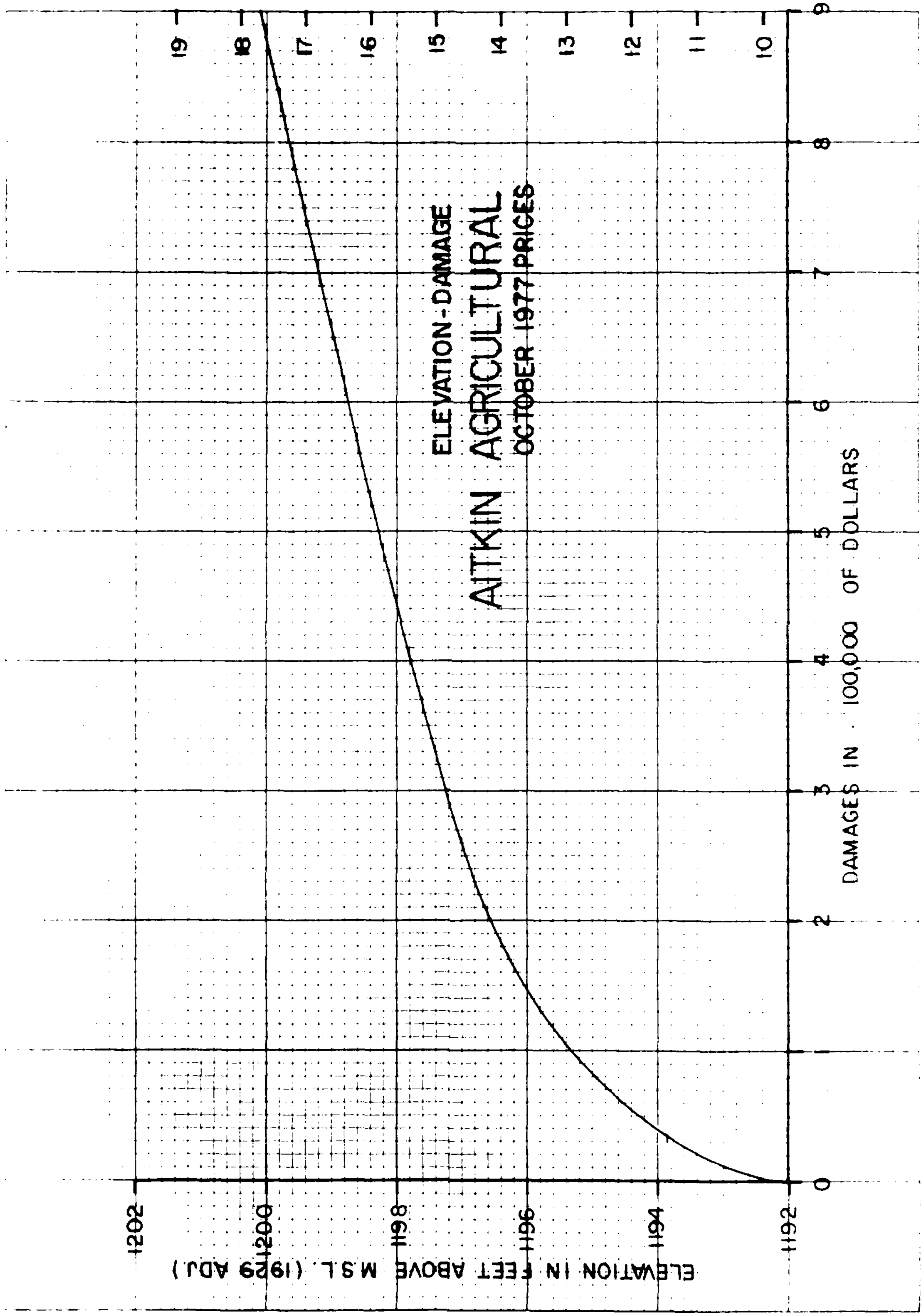
APRIL 1978

GULL LAKE
ELEVATION DAMAGE CURVE

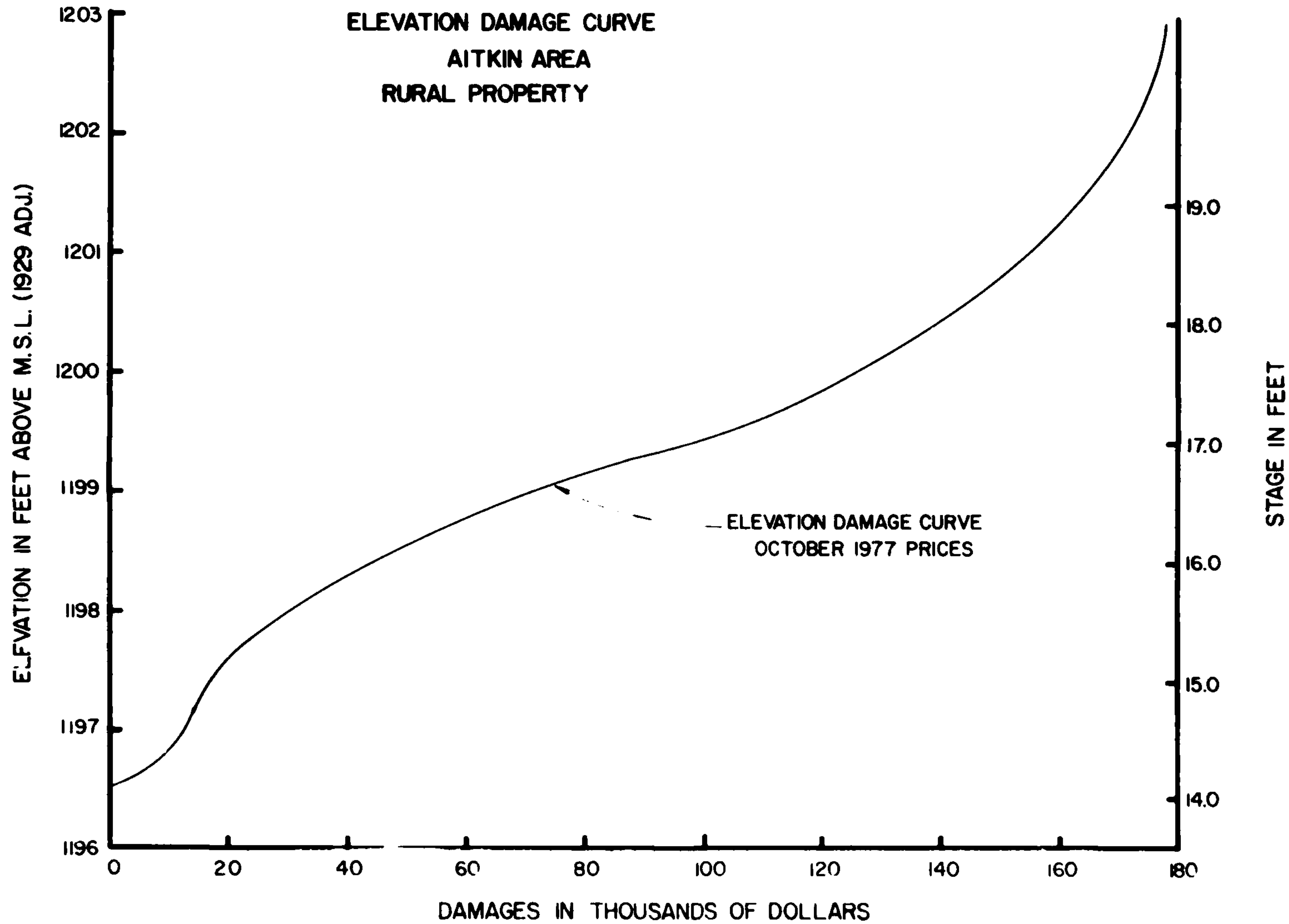


APRIL 1978


ELEVATION DAMAGE CURVE
URBAN AITKIN
ELEVATION DAMAGE CURVE
OCTOBER 1977 PRICES
DAMAGES IN THOUSANDS OF DOLLARS
100
200
300
400
500
600
700
800
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)
1192
1194
1196
1198
1200
1202
1204
1206
STAGE IN FEET
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0



ELEVATION-DAMAGE
AITKIN AGRICULTURAL
OCTOBER 1977 PRICES
DAMAGES IN 100,000 OF DOLLARS
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)
0
1
2
3
4
5
6
7
8
9
1192
1194
1196
1198
1200
1202
10
11
12
13
14
15
16
17
18
19


ELEVATION DAMAGE CURVE
AITKIN AREA
RURAL PROPERTY
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)
1203
1202
1201
1200
1199
1198
1197
1196
0
20
40
60
80
100
120
140
160
180
DAMAGES IN THOUSANDS OF DOLLARS
STAGE IN FEET
19.0
18.0
17.0
16.0
15.0
14.0
ELEVATION DAMAGE CURVE
OCTOBER 1977 PRICES

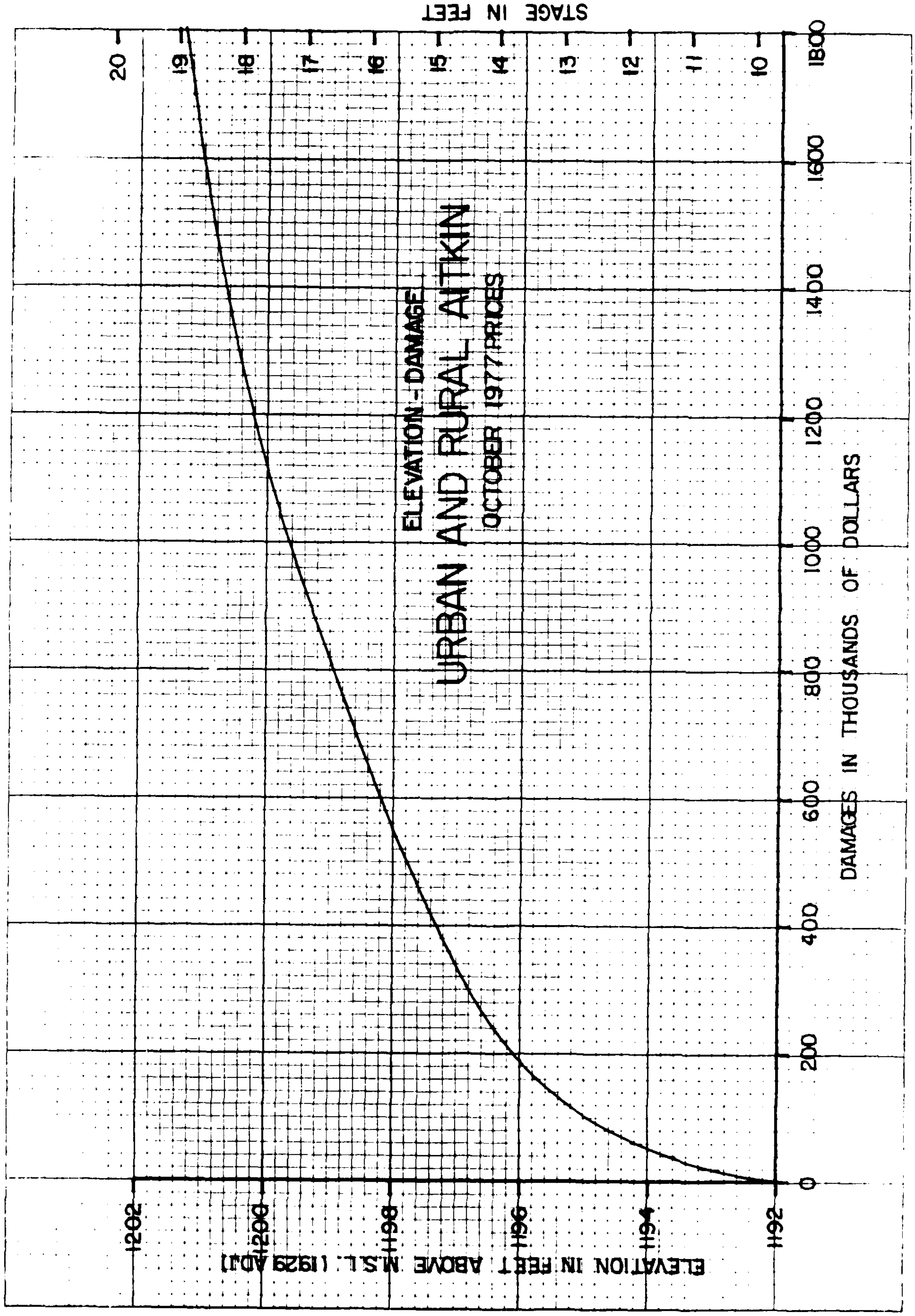
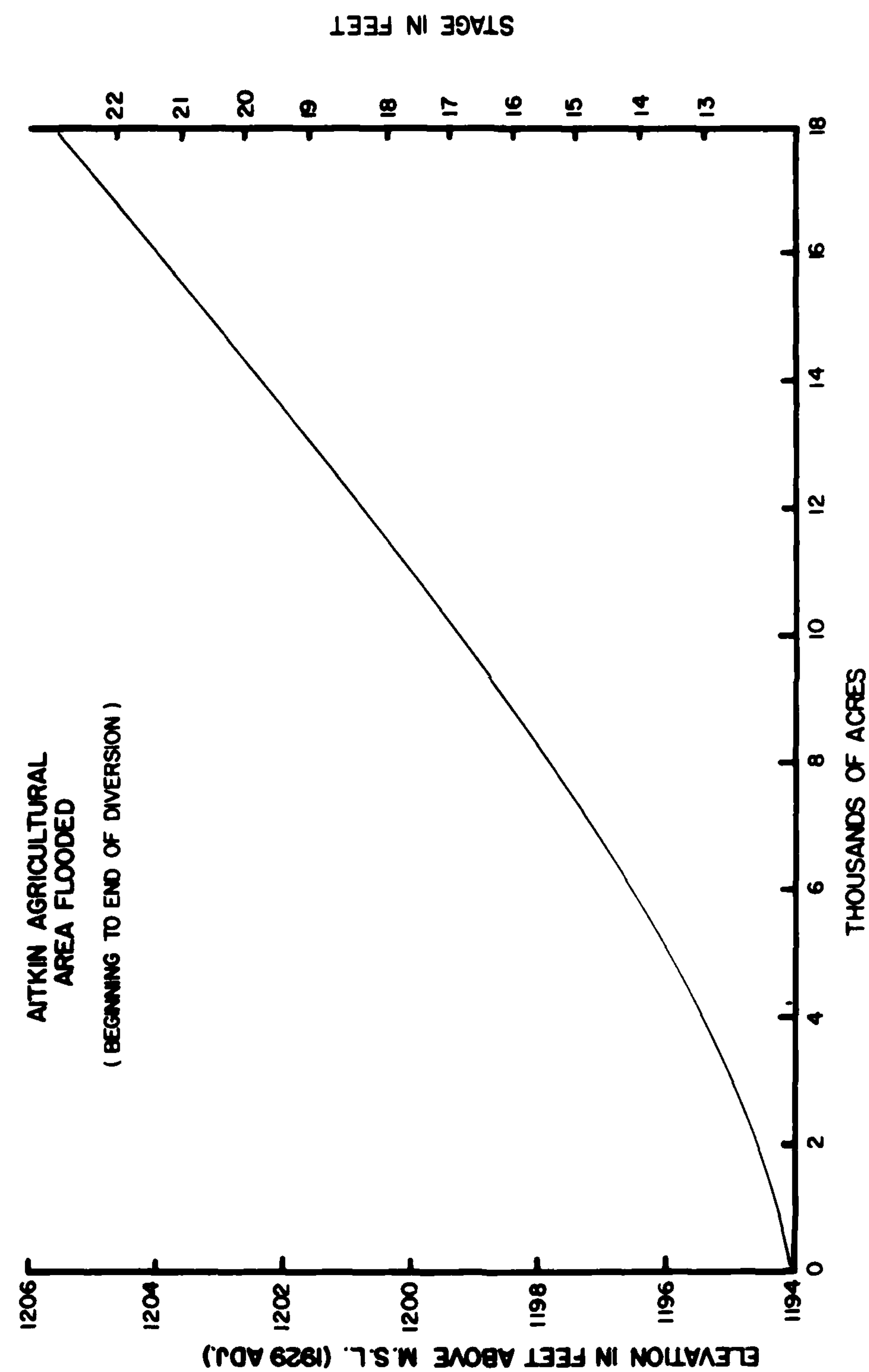
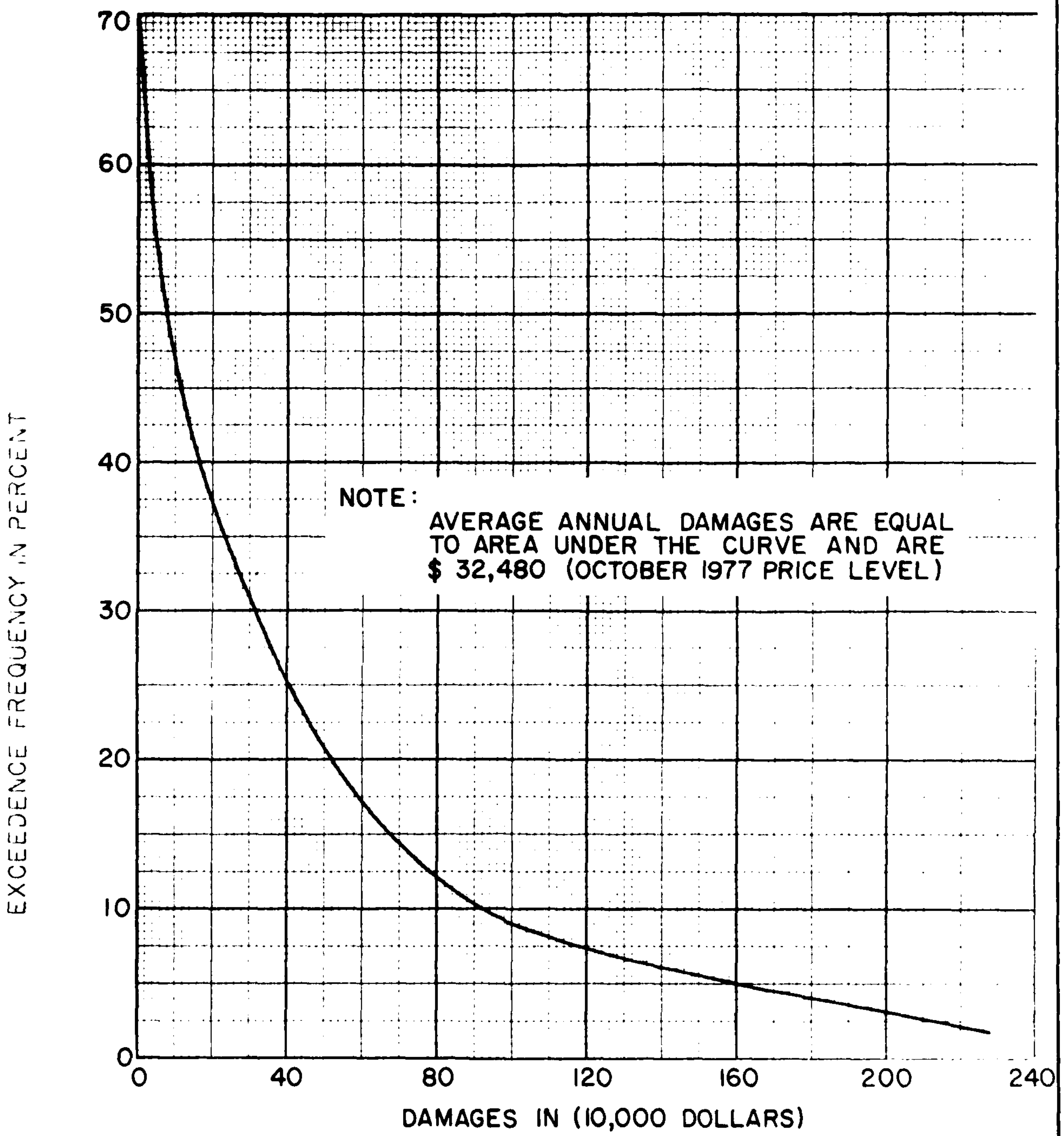

ELEVATION - DAMAGE
URBAN AND RURAL AITKIN
OCTOBER 1977 PRICES
STAGE IN FEET
10
11
12
13
14
15
16
17
18
19
20
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ)
1192
1194
1196
1198
1200
1202
DAMAGES IN THOUSANDS OF DOLLARS
0
200
400
600
800
1000
1200
1400
1600
1800

Plate A-27

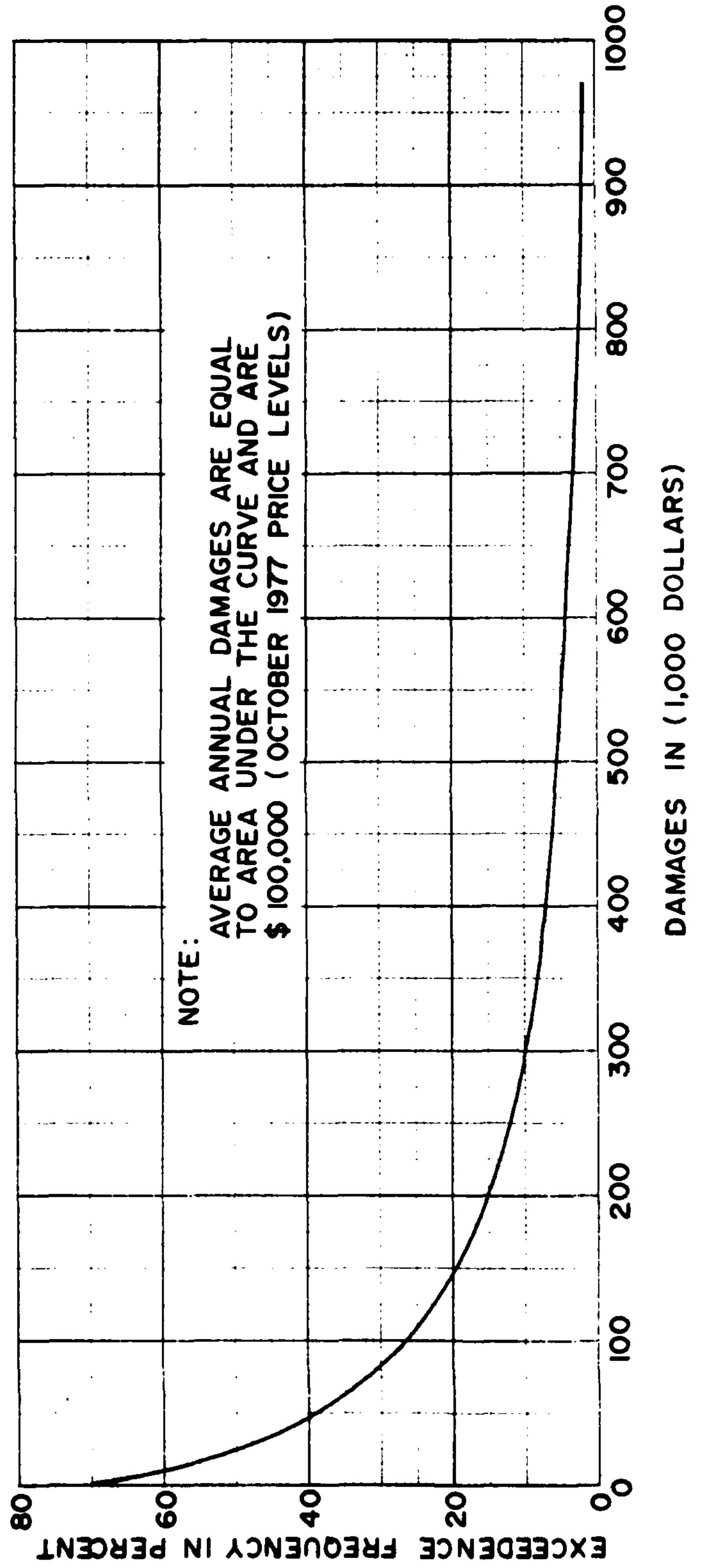

AITKIN AGRICULTURAL
AREA FLOODED
(BEGINNING TO END OF DIVERSION)
STAGE IN FEET
22
21
20
19
18
17
16
15
14
13
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)
1206
1204
1202
1200
1198
1196
1194
0
2
4
6
8
10
12
14
16
18
THOUSANDS OF ACRES



MISSISSIPPI RIVER HEADWATERS STUDY

HIGH WATER FREQUENCY-DAMAGE
WINNIBIGOSH LAKE

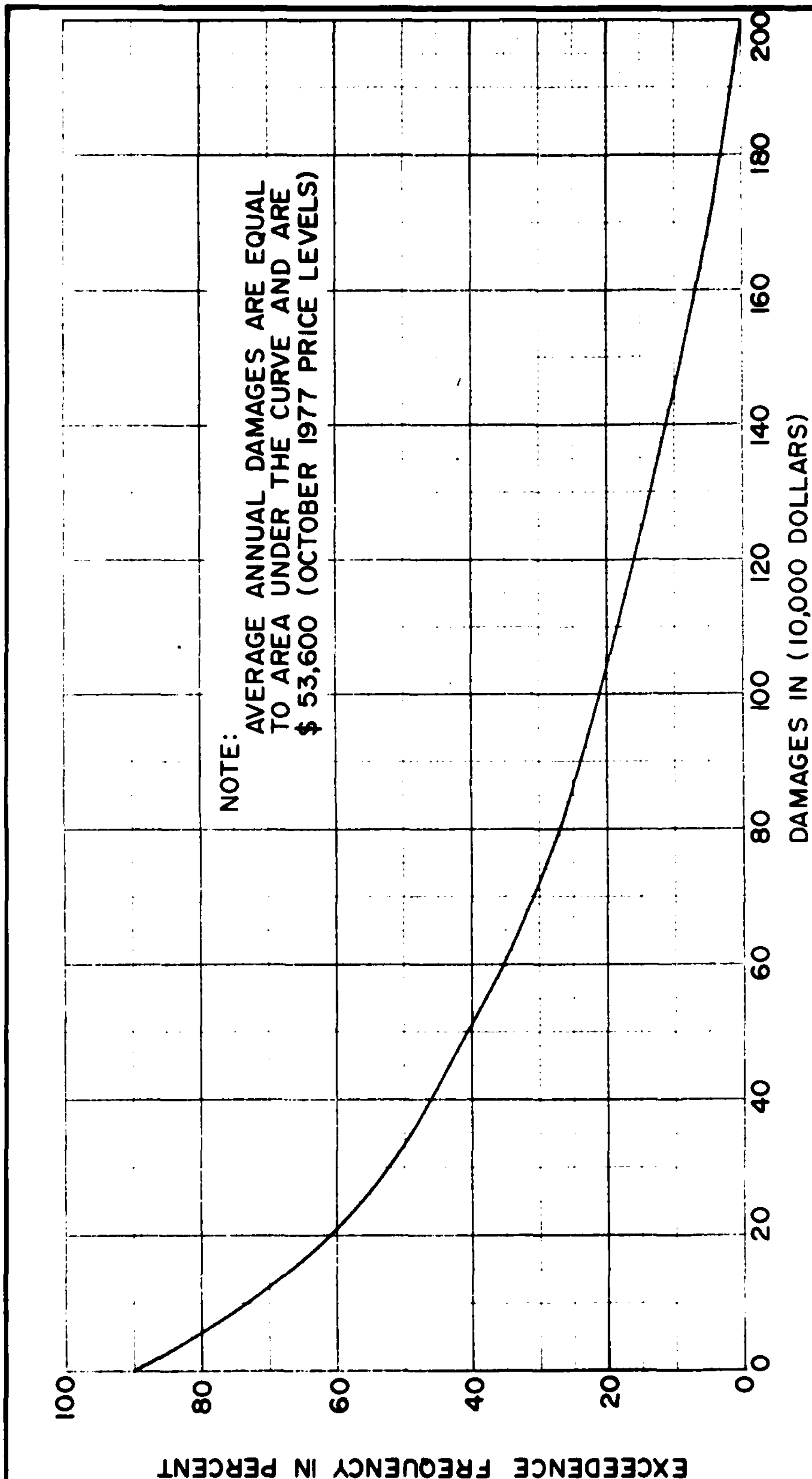
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
HIGH WATER FREQUENCY-DAMAGE

LEECH LAKE

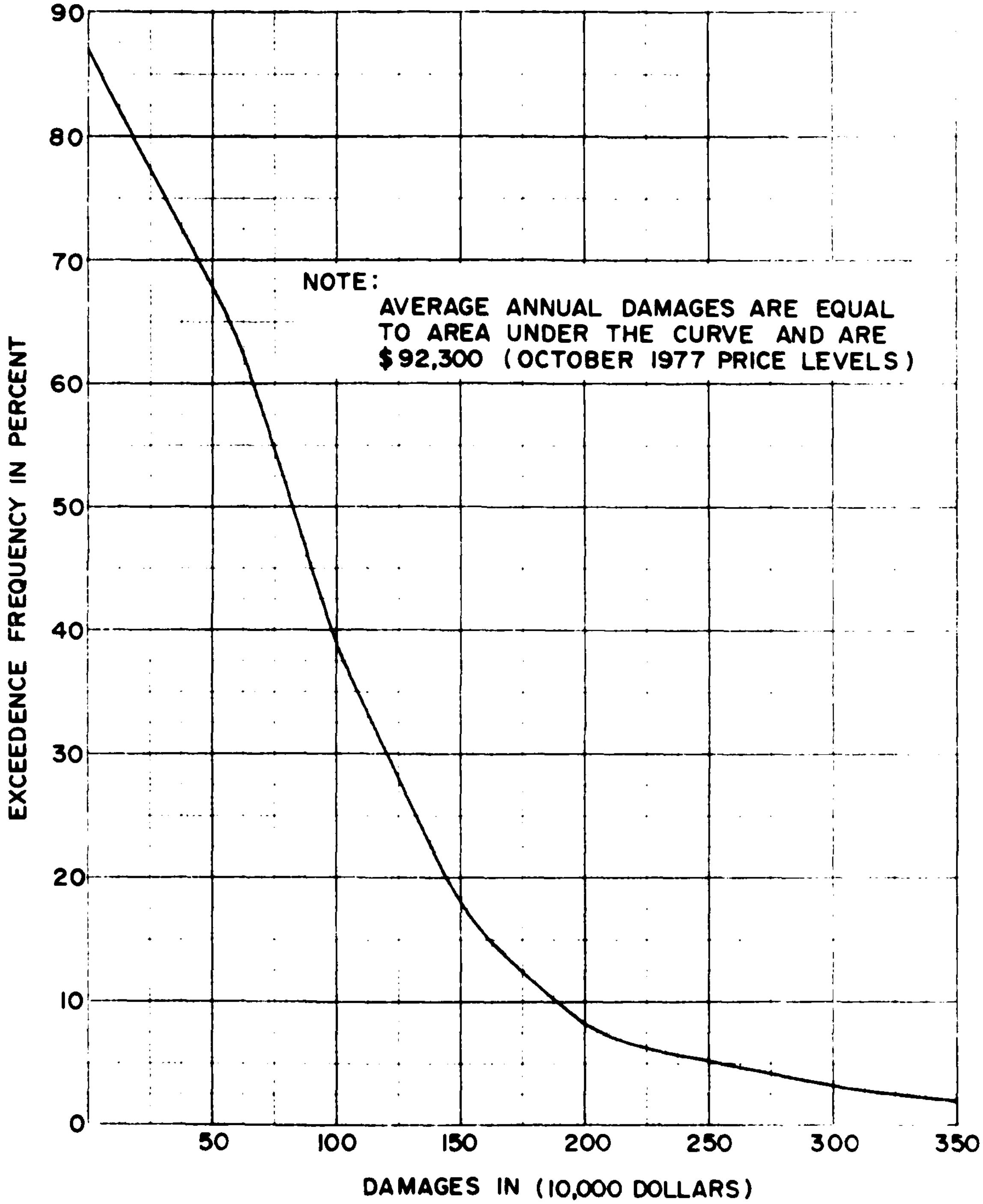
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
HIGH WATER FREQUENCY - DAMAGE

POKEGAMA LAKE

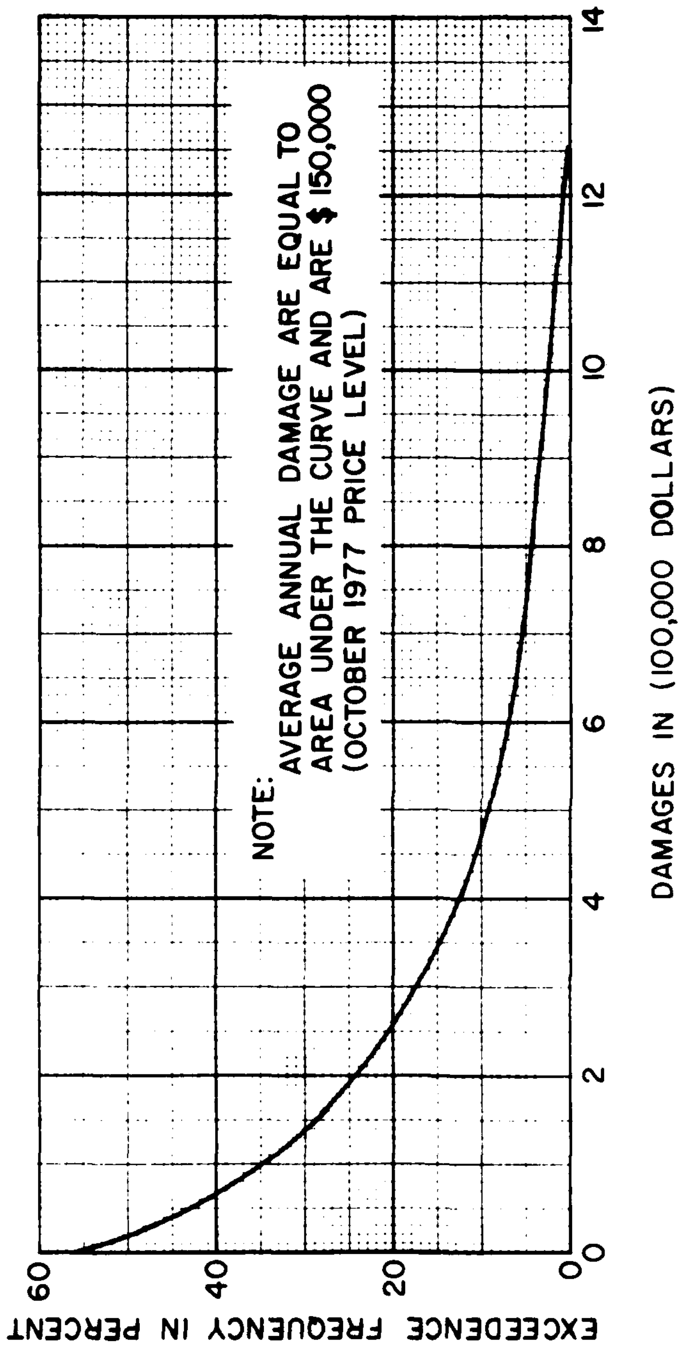
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
HIGH WATER FREQUENCY - DAMAGE

BIG SANDY

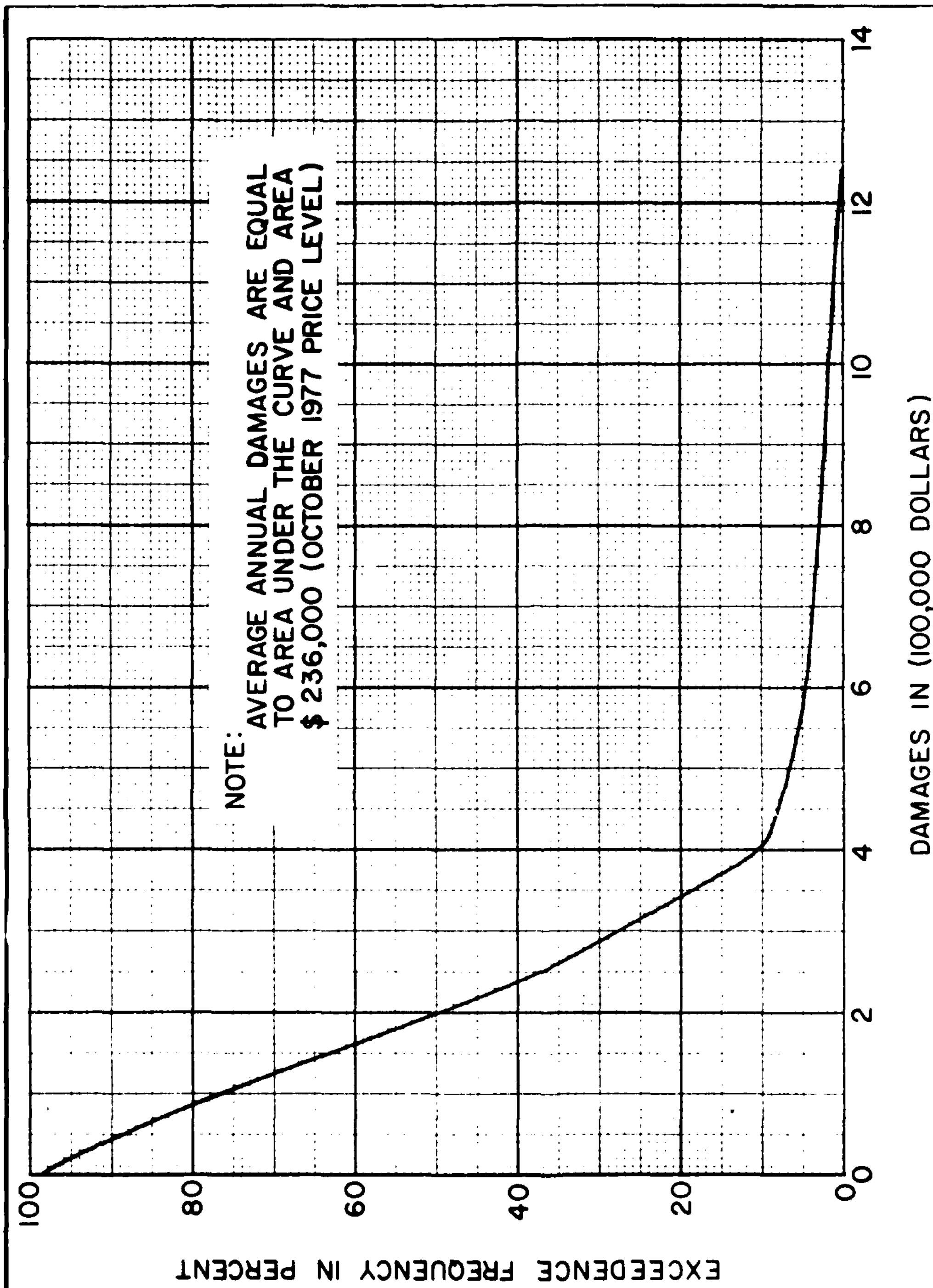
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE – FREQUENCY ANALYSIS

HIGH WATER FREQUENCY-DAMAGE
PINE RIVER LAKES

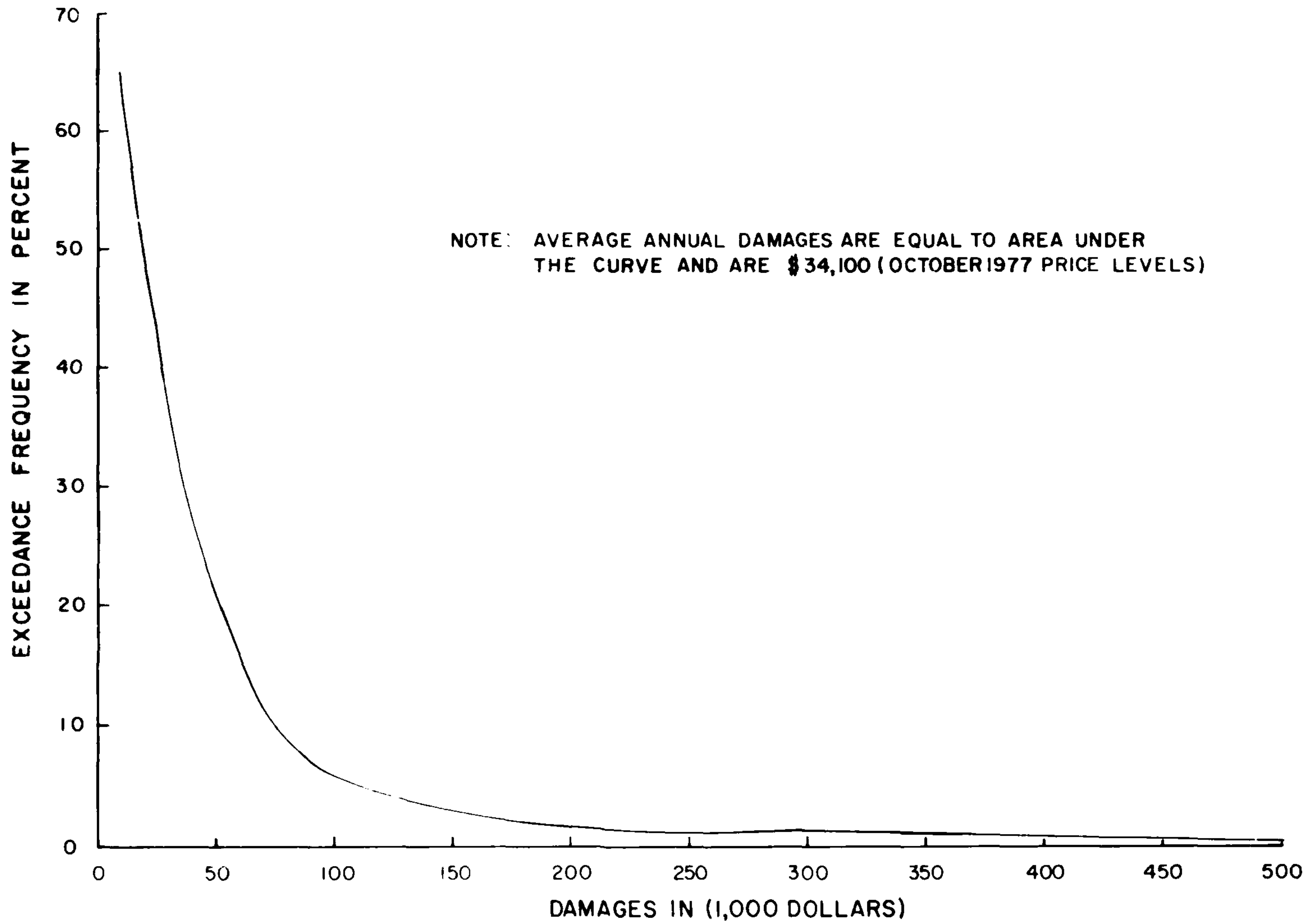
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE – FREQUENCY ANALYSIS

HIGH WATER FREQUENCY – DAMAGE
GULL LAKE

ST. PAUL DISTRICT CORPS OF ENGINEERS

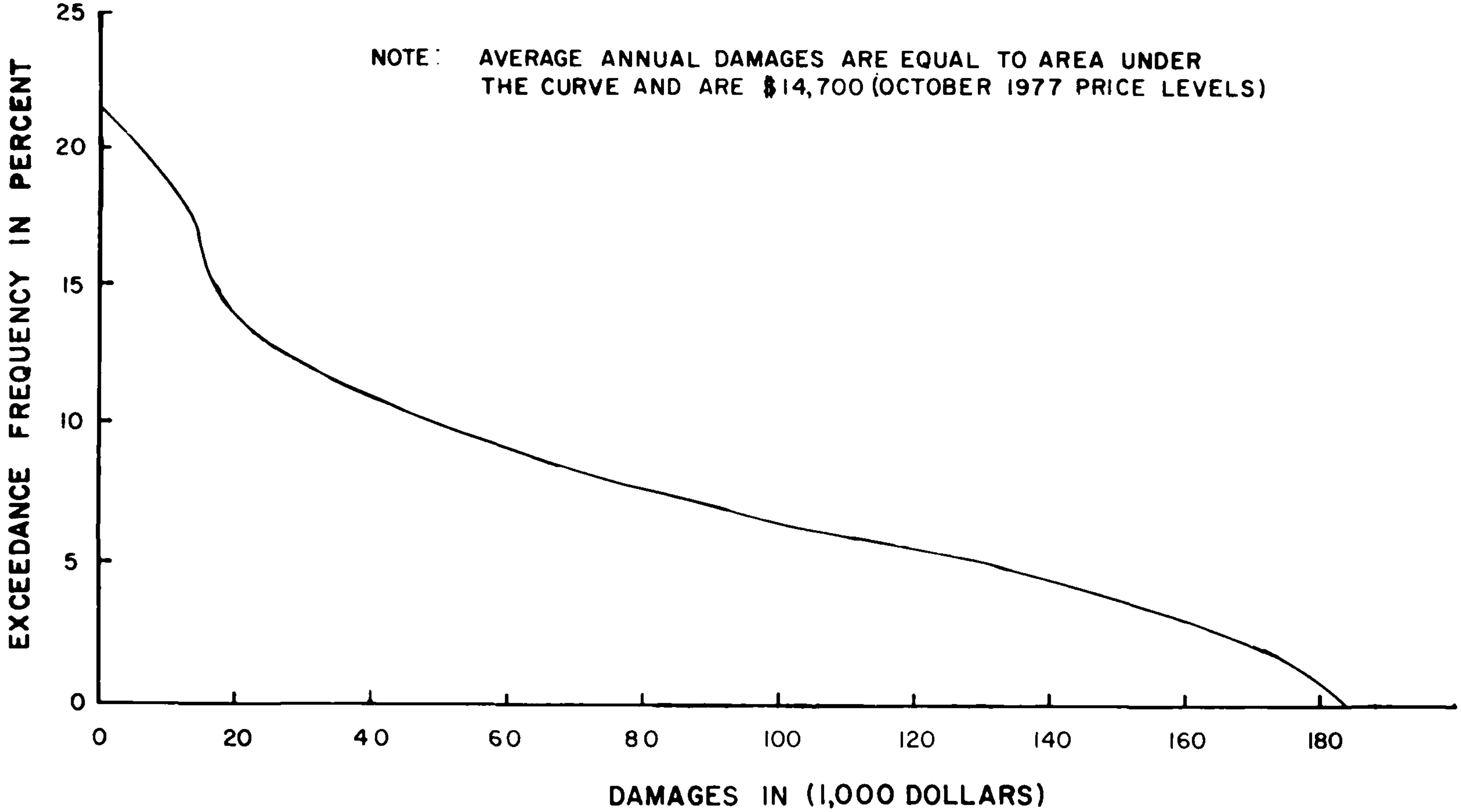


MISSISSIPPI RIVER HEADWATERS STUDY

FLOOD FREQUENCY-DAMAGE

URBAN AITKIN

ST. PAUL DISTRICT CORPS OF ENGINEERS



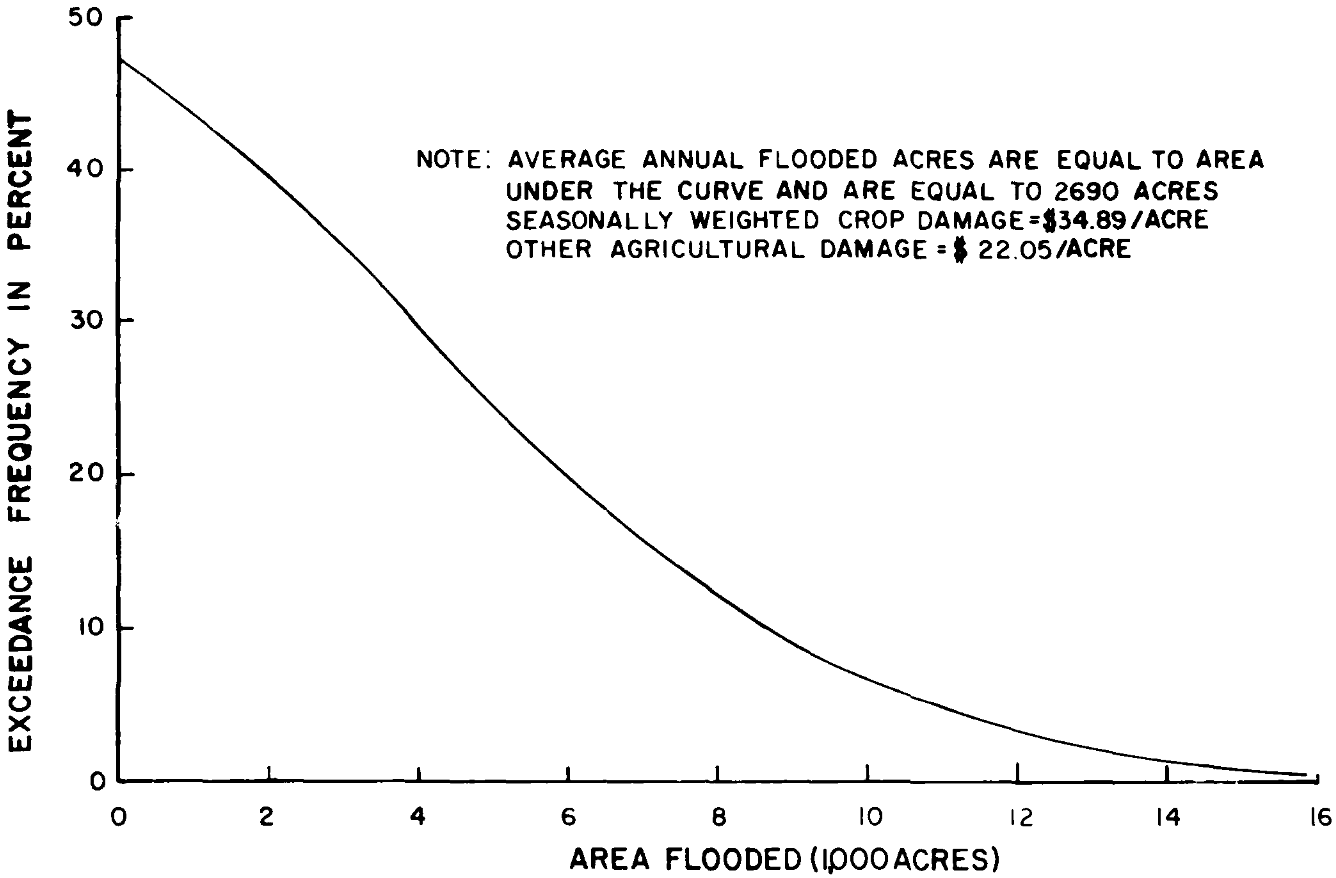
MISSISSIPPI RIVER HEADWATERS STUDY

FLOOD FREQUENCY-DAMAGE

RURAL RESIDENTIAL PROPERTY

ST. PAUL DISTRICT CORPS OF ENGINEERS

Plate A-36



MISSISSIPPI RIVER HEADWATERS STUDY

AREA FLOODED FREQUENCY

AITKIN AGRICULTURAL

ST. PAUL DISTRICT CORPS OF ENGINEERS

Plate A-37

PLAN 1

TIME SERIES DATA PLOTS
AND
ANNUAL MAX/MIN DATA TABLES

Plate A-38

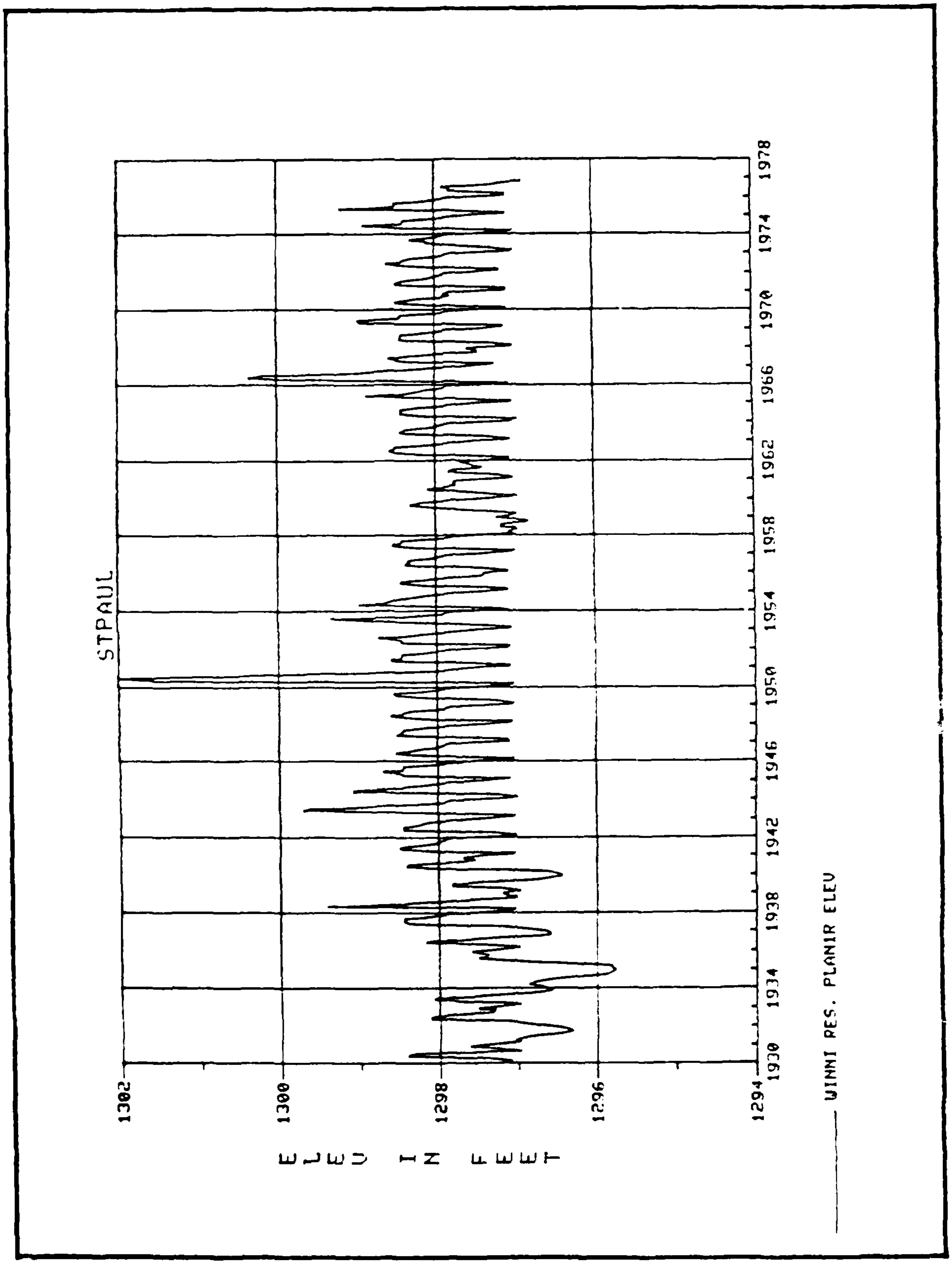
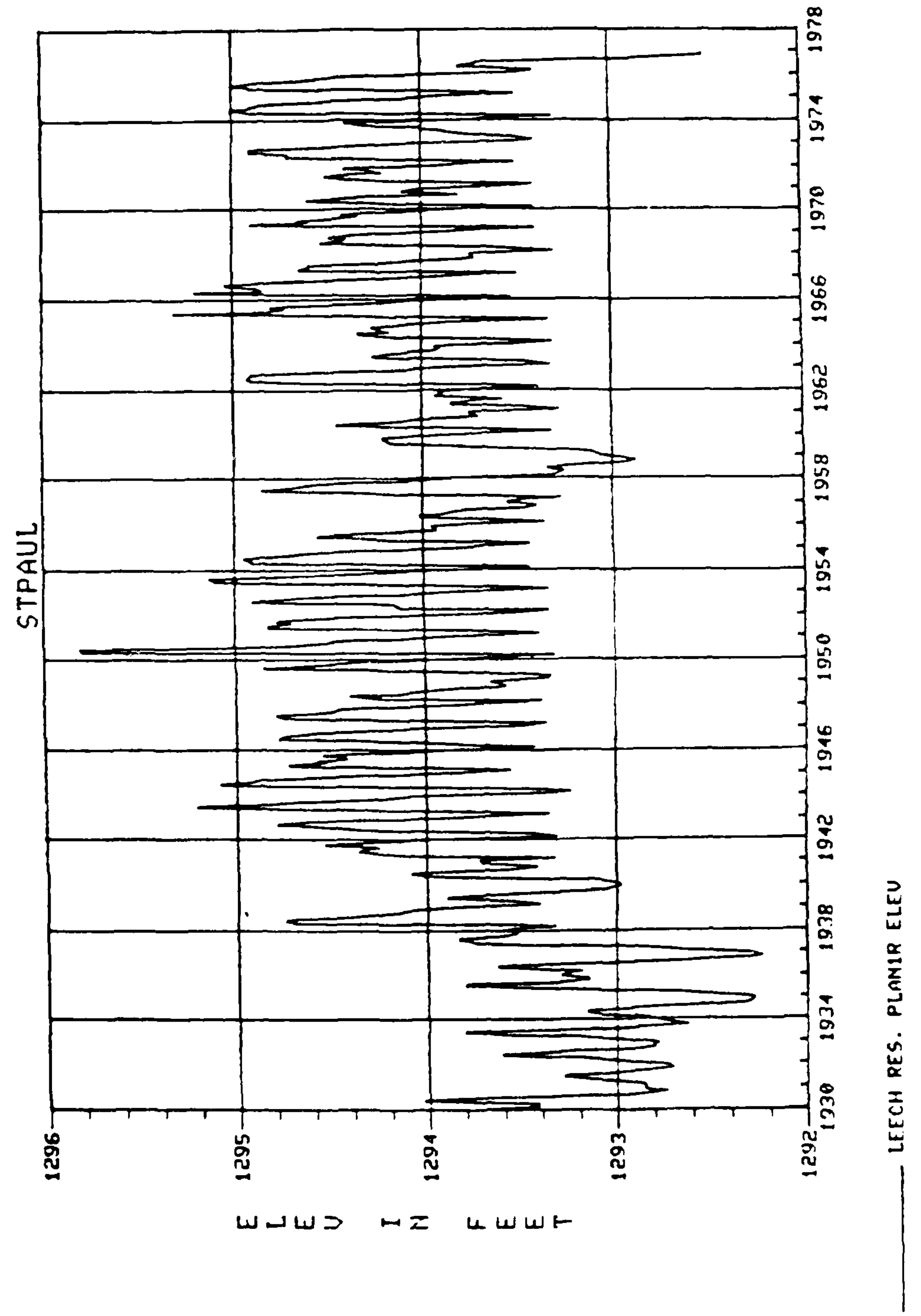

STPAUL
ELEV IN FEET
1302
1300
1298
1296
1294
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
WINNI RES. PLANIR ELEV

Plate A-39


STPAUL
ELEV IN FEET
1296
1295
1294
1293
1292
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
LEECH RES. PLANIR ELEV

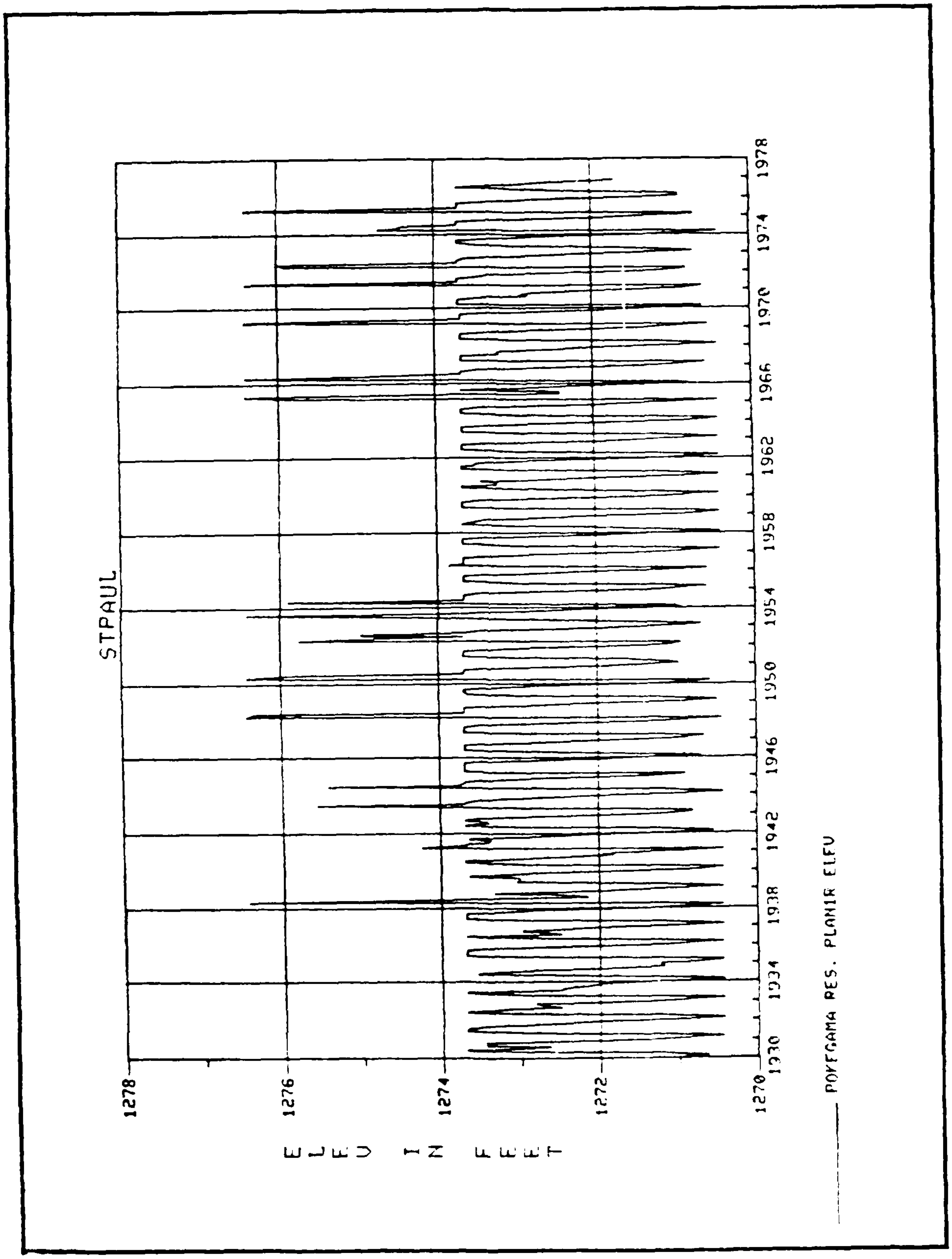

STPAUL
ELEV IN FEET
1278
1276
1274
1272
1270
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978

Plate A-

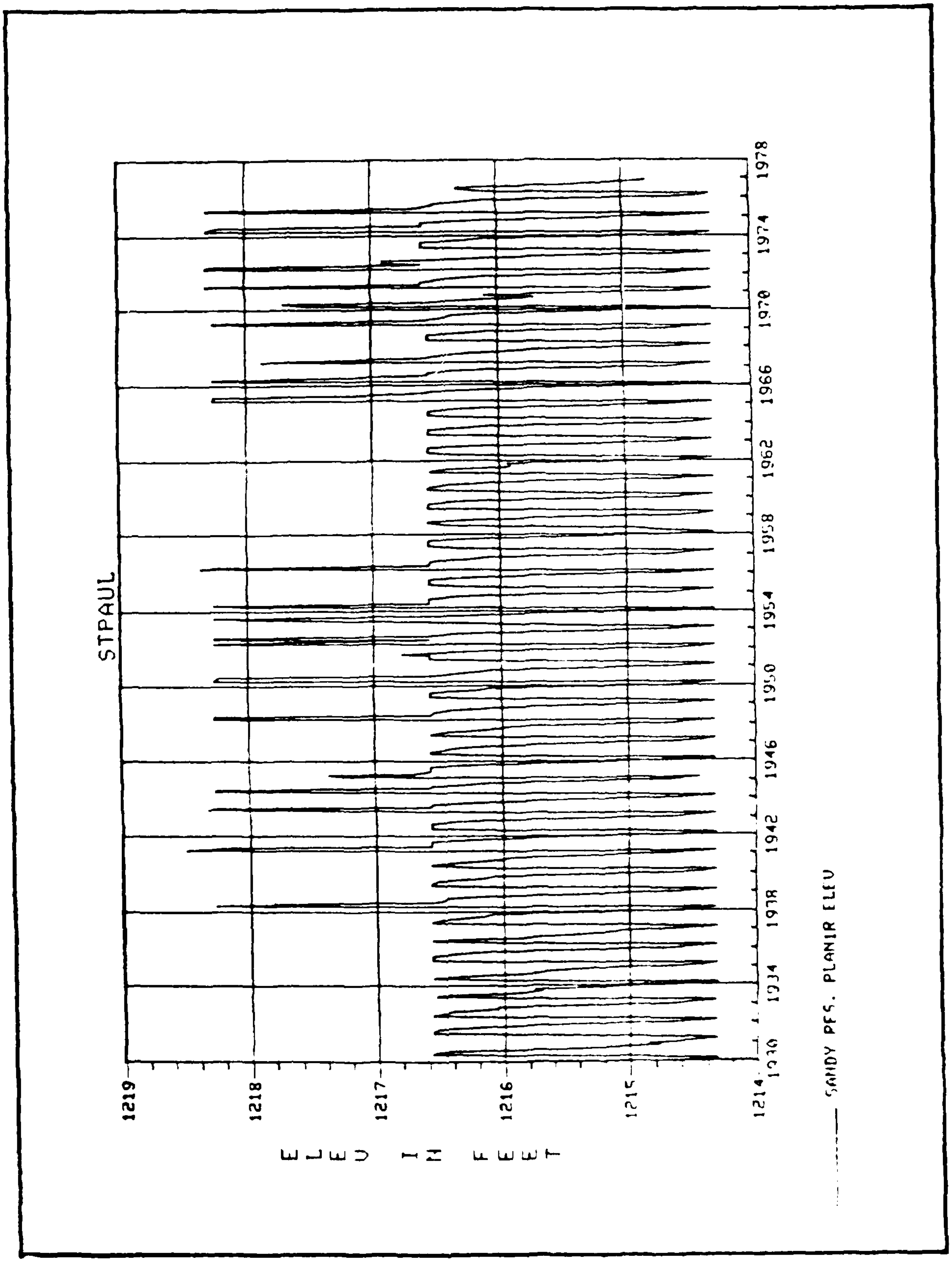
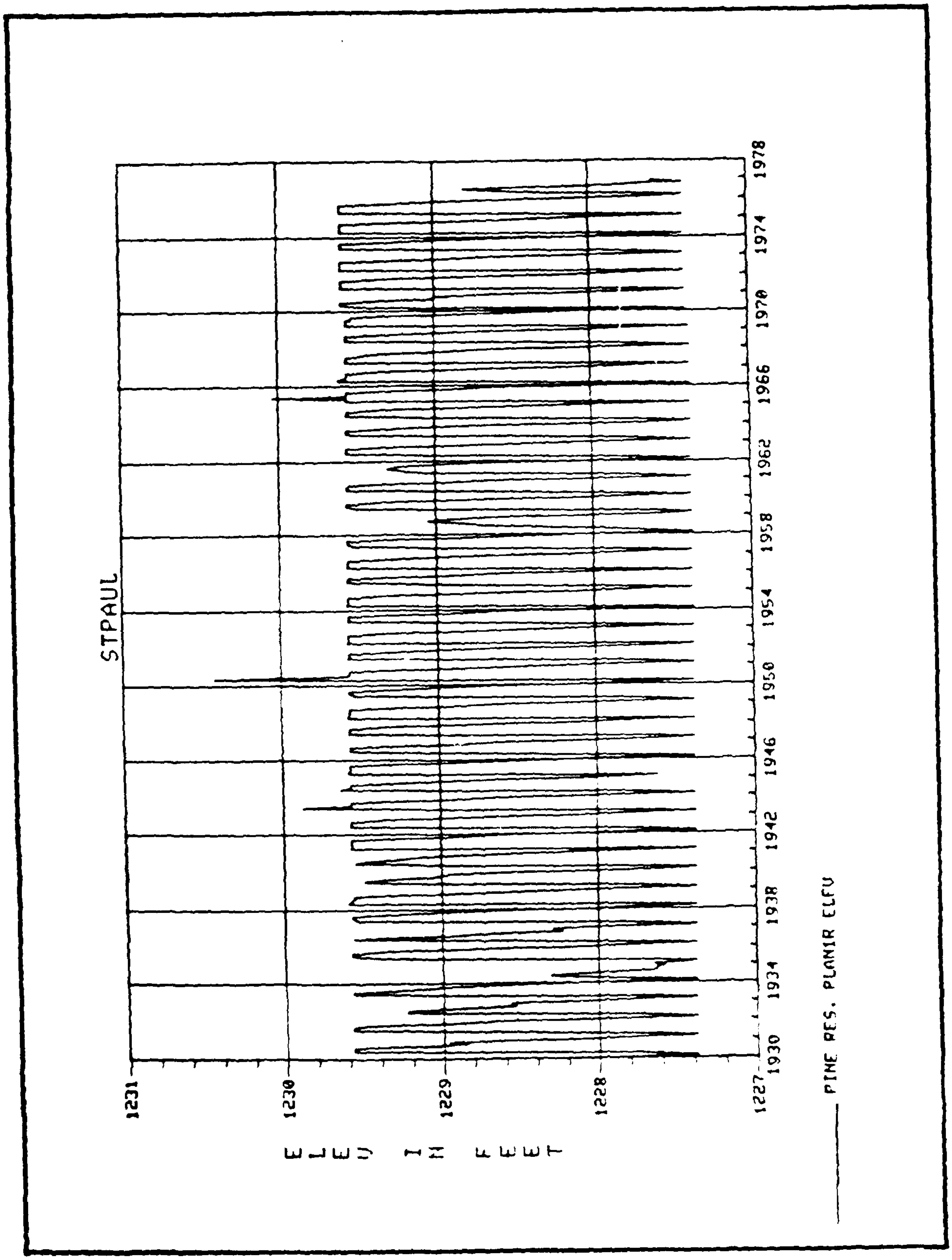

STPAUL
ELEV IN FEET
1219
1218
1217
1216
1215
1214
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
SANDY RES. PLANIR ELEV

Plate A-



STPAUL
ELEV IN FEET
1231
1230
1229
1228
1227
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
PINE RES. PLANIR ELEV

Plate A-

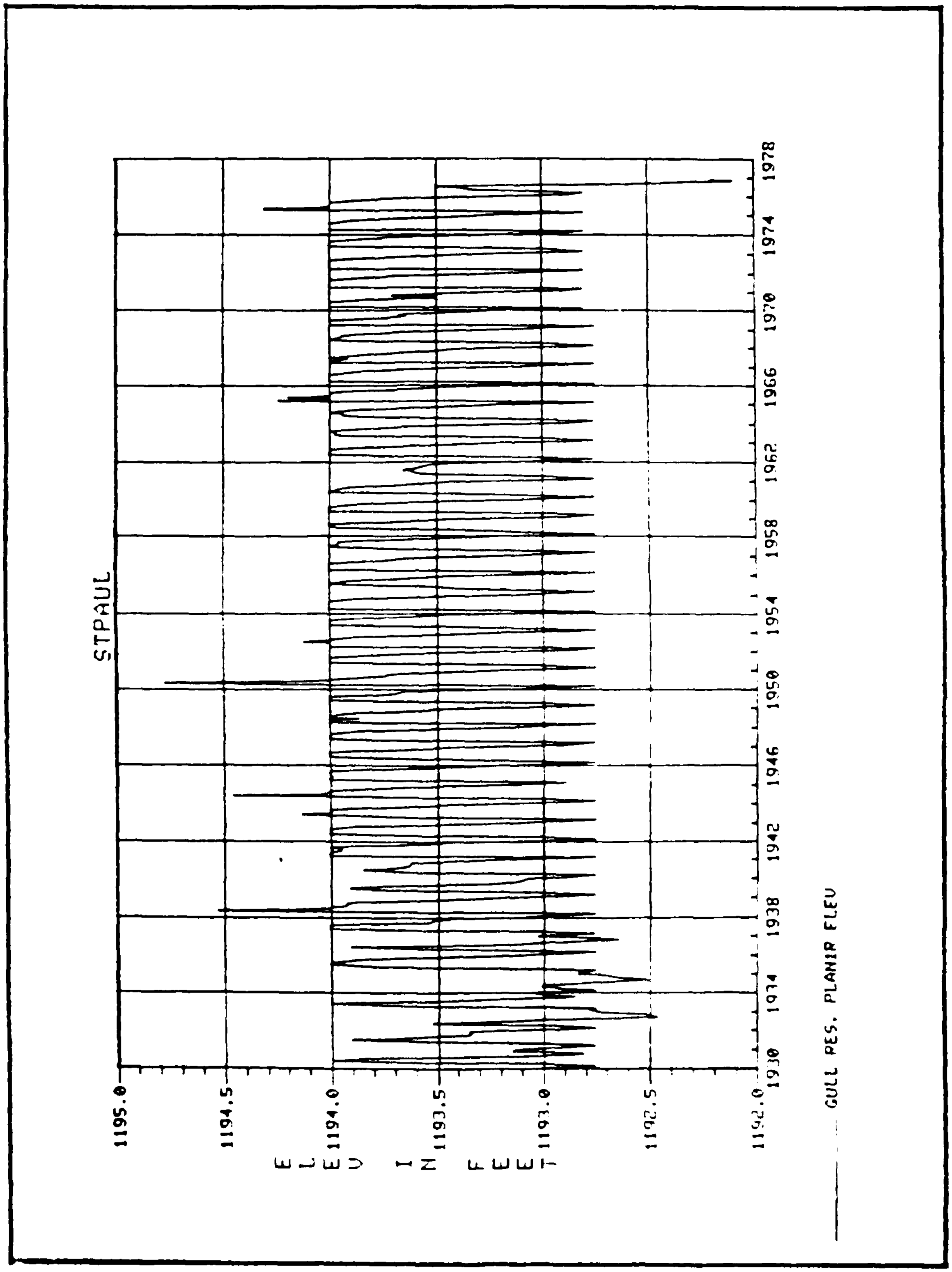

STPAUL
1195.0
1194.5
1194.0
1193.5
1193.0
1192.5
1192.0
ELEV IN FEET
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
GULL RES. PLANIR ELEV

Plate A-..

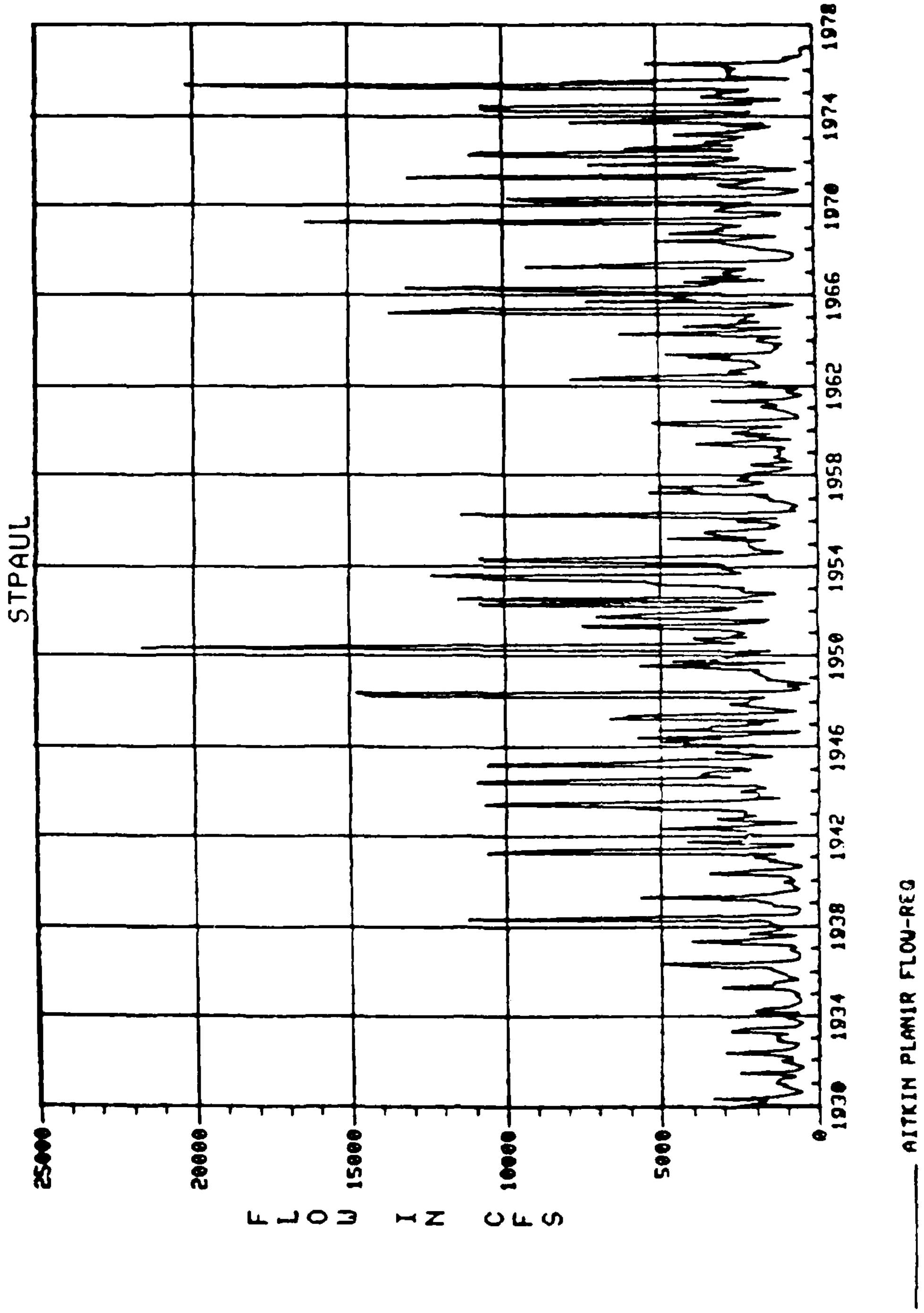

STPAUL
FLOW IN CFS
25000
20000
15000
10000
5000
0
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
AITKIN PLANIR FLOW-REQ

Plate A-45

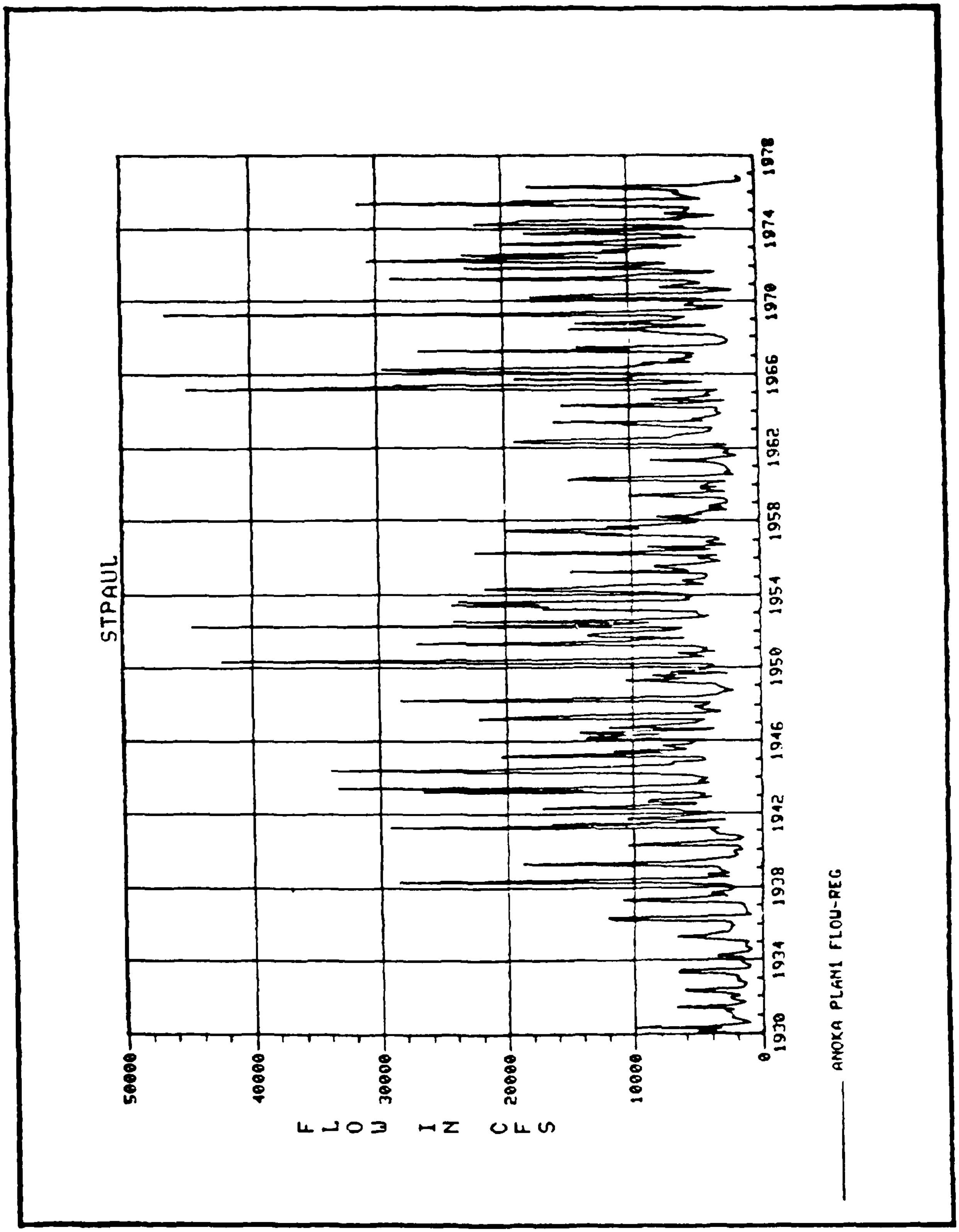

STPAUL
FLOW IN CFS
50000
40000
30000
20000
10000
0
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
ANOKA PLAN1 FLOW-REG

Plate A-[illegible]6

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- WINNI RESERVOIR ELEVATION

......EVENTS ANALYZED......				......ORDERED EVENTS......			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1298.4	1	1950	1302.0	2.08
5	-1	1931	1297.0	2	1966	1300.4	4.17
6	-1	1932	1298.1	3	1943	1299.7	6.25
6	-1	1933	1298.0	4	1938	1299.4	8.33
5	-1	1934	1296.8	5	1953	1299.3	10.42
8	-1	1935	1297.5	6	1975	1299.2	12.50
6	-1	1936	1298.1	7	1944	1299.1	14.58
7	-1	1937	1298.4	8	1954	1299.0	16.67
5	-1	1938	1299.4	9	1969	1299.0	18.75
7	-1	1939	1297.8	10	1974	1298.9	20.83
6	-1	1940	1298.4	11	1965	1298.9	22.92
6	-1	1941	1298.5	12	1952	1298.7	25.00
6	-1	1942	1298.4	13	1945	1298.7	27.08
6	-1	1943	1299.7	14	1967	1298.6	29.17
6	-1	1944	1299.1	15	1948	1298.6	31.25
6	-1	1945	1298.7	16	1951	1298.6	33.33
6	-1	1946	1298.5	17	1962	1298.6	35.42
6	-1	1947	1298.5	18	1972	1298.6	37.50
6	-1	1948	1298.6	19	1949	1298.5	39.58
8	-1	1949	1298.5	20	1957	1298.5	41.67
6	-1	1950	1302.0	21	1971	1298.5	43.75
6	-1	1951	1298.6	22	1946	1298.5	45.83
8	-1	1952	1298.7	23	1970	1298.5	47.92
8	-1	1953	1299.3	24	1947	1298.5	50.00
5	-1	1954	1299.0	25	1941	1298.5	52.08
6	-1	1955	1298.4	26	1955	1298.4	54.17
6	-1	1956	1298.4	27	1942	1298.4	56.25
6	-1	1957	1298.5	28	1963	1298.4	58.33
7	-1	1958	1297.2	29	1964	1298.4	60.42
9	-1	1959	1298.3	30	1968	1298.4	62.50
7	-1	1960	1298.1	31	1937	1298.4	64.58
6	-1	1961	1297.8	32	1940	1298.4	66.67
7	-1	1962	1298.6	33	1930	1298.4	68.75
7	-1	1963	1298.4	34	1956	1298.4	70.83
6	-1	1964	1298.4	35	1959	1298.3	72.92
6	-1	1965	1298.9	36	1973	1298.3	75.00
6	-1	1966	1300.4	37	1936	1298.1	77.08
6	-1	1967	1298.6	38	1932	1298.1	79.17
6	-1	1968	1298.4	39	1960	1298.1	81.25
6	-1	1969	1299.0	40	1933	1298.0	83.33
6	-1	1970	1298.5	41	1976	1297.8	85.42
6	-1	1971	1298.5	42	1939	1297.8	87.50
6	-1	1972	1298.6	43	1961	1297.8	89.58
9	-1	1973	1298.3	44	1935	1297.5	91.67
6	-1	1974	1298.9	45	1958	1297.2	93.75
5	-1	1975	1299.2	46	1931	1297.0	95.83
5	-1	1976	1297.8	47	1934	1296.8	97.92

Plate A-47

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- WINNI RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
9	-1	1930	1297.0	1	1934	1296.0	2.08
9	-1	1931	1296.3	2	1931	1296.3	4.17
9	-1	1932	1297.6	3	1935	1296.4	6.25
9	-1	1933	1297.1	4	1930	1297.0	8.33
9	-1	1934	1296.0	5	1958	1297.0	10.42
5	-1	1935	1296.4	6	1939	1297.0	12.50
9	-1	1936	1297.2	7	1933	1297.1	14.58
5	-1	1937	1297.9	8	1936	1297.2	16.67
9	-1	1938	1297.4	9	1959	1297.3	18.75
9	-1	1939	1297.0	10	1976	1297.3	20.83
9	-1	1940	1297.8	11	1938	1297.4	22.92
9	-1	1941	1298.0	12	1961	1297.4	25.00
5	-1	1942	1298.0	13	1960	1297.6	27.08
5	-1	1943	1298.1	14	1932	1297.6	29.17
5	-1	1944	1297.9	15	1949	1297.6	31.25
5	-1	1945	1298.4	16	1973	1297.6	33.33
9	-1	1946	1298.0	17	1967	1297.8	35.42
5	-1	1947	1298.3	18	1940	1297.8	37.50
9	-1	1948	1298.3	19	1970	1297.8	39.58
5	-1	1949	1297.6	20	1937	1297.9	41.67
9	-1	1950	1299.6	21	1955	1297.9	43.75
7	-1	1951	1298.4	22	1953	1297.9	45.83
9	-1	1952	1298.4	23	1944	1297.9	47.92
5	-1	1953	1297.9	24	1941	1298.0	50.00
9	-1	1954	1298.4	25	1942	1298.0	52.08
9	-1	1955	1297.9	26	1963	1298.0	54.17
5	-1	1956	1298.2	27	1968	1298.0	56.25
5	-1	1957	1298.2	28	1946	1298.0	58.33
5	-1	1958	1297.0	29	1971	1298.1	60.42
5	-1	1959	1297.3	30	1962	1298.1	62.50
5	-1	1960	1297.6	31	1964	1298.1	64.58
9	-1	1961	1297.4	32	1943	1298.1	66.67
5	-1	1962	1298.1	33	1965	1298.2	68.75
5	-1	1963	1298.0	34	1957	1298.2	70.83
5	-1	1964	1298.1	35	1956	1298.2	72.92
9	-1	1965	1298.2	36	1947	1298.3	75.00
9	-1	1966	1299.0	37	1948	1298.3	77.08
9	-1	1967	1297.8	38	1972	1298.3	79.17
5	-1	1968	1298.0	39	1954	1298.4	81.25
8	-1	1969	1298.4	40	1952	1298.4	83.33
9	-1	1970	1297.8	41	1969	1298.4	85.42
9	-1	1971	1298.1	42	1945	1298.4	87.50
9	-1	1972	1298.3	43	1951	1298.4	89.58
5	-1	1973	1297.6	44	1974	1298.4	91.67
7	-1	1974	1298.4	45	1975	1298.5	93.75
9	-1	1975	1298.5	46	1966	1299.0	95.83
9	-1	1976	1297.3	47	1950	1299.6	97.92

Plate A-58

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- LEECH RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1294.0	1	1950	1295.8	2.08
6	-1	1931	1293.3	2	1965	1295.3	4.17
6	-1	1932	1293.6	3	1943	1295.2	6.25
6	-1	1933	1293.8	4	1966	1295.2	8.33
5	-1	1934	1293.1	5	1953	1295.1	10.42
7	-1	1935	1293.8	6	1944	1295.1	12.50
5	-1	1936	1293.6	7	1974	1295.0	14.58
8	-1	1937	1293.8	8	1975	1295.0	16.67
6	-1	1938	1294.7	9	1954	1294.9	18.75
6	-1	1939	1293.9	10	1962	1294.9	20.83
6	-1	1940	1294.1	11	1952	1294.9	22.92
9	-1	1941	1294.4	12	1969	1294.9	25.00
9	-1	1942	1294.8	13	1972	1294.9	27.08
6	-1	1943	1295.2	14	1949	1294.9	29.17
7	-1	1944	1295.1	15	1957	1294.8	31.25
5	-1	1945	1294.7	16	1951	1294.8	33.33
7	-1	1946	1294.8	17	1947	1294.8	35.42
7	-1	1947	1294.8	18	1942	1294.8	37.50
5	-1	1948	1294.4	19	1946	1294.8	39.58
8	-1	1949	1294.9	20	1938	1294.7	41.67
6	-1	1950	1295.8	21	1945	1294.7	43.75
6	-1	1951	1294.8	22	1967	1294.6	45.83
8	-1	1952	1294.9	23	1970	1294.6	47.92
8	-1	1953	1295.1	24	1955	1294.6	50.00
7	-1	1954	1294.9	25	1968	1294.5	52.08
7	-1	1955	1294.6	26	1971	1294.5	54.17
6	-1	1956	1294.0	27	1960	1294.4	56.25
7	-1	1957	1294.8	28	1941	1294.4	58.33
7	-1	1958	1293.3	29	1948	1294.4	60.42
9	-1	1959	1294.2	30	1964	1294.3	62.50
6	-1	1960	1294.4	31	1963	1294.3	64.58
6	-1	1961	1293.8	32	1959	1294.2	66.67
7	-1	1962	1294.9	33	1940	1294.1	68.75
7	-1	1963	1294.3	34	1956	1294.0	70.83
7	-1	1964	1294.3	35	1930	1294.0	72.92
6	-1	1965	1295.3	36	1973	1294.0	75.00
5	-1	1966	1295.2	37	1939	1293.9	77.08
5	-1	1967	1294.6	38	1961	1293.8	79.17
7	-1	1968	1294.5	39	1937	1293.8	81.25
5	-1	1969	1294.9	40	1933	1293.8	83.33
6	-1	1970	1294.6	41	1935	1293.8	85.42
7	-1	1971	1294.5	42	1976	1293.8	87.50
9	-1	1972	1294.9	43	1936	1293.6	89.58
9	-1	1973	1294.0	44	1932	1293.6	91.67
6	-1	1974	1295.0	45	1958	1293.3	93.75
7	-1	1975	1295.0	46	1931	1293.3	95.83
5	-1	1976	1293.8	47	1934	1293.1	97.92

Plate A-9

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- LEECH RESERVOIR ELEVATION

MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
9	-1	1930	1292.9	1	1934	1292.3	2.08
9	-1	1931	1292.9	2	1936	1292.4	4.17
9	-1	1932	1292.9	3	1933	1292.7	6.25
9	-1	1933	1292.7	4	1930	1292.9	8.33
9	-1	1934	1292.3	5	1931	1292.9	10.42
5	-1	1935	1293.1	6	1932	1292.9	12.50
9	-1	1936	1292.4	7	1976	1292.9	14.58
5	-1	1937	1293.5	8	1958	1293.0	16.67
9	-1	1938	1294.2	9	1935	1293.1	18.75
9	-1	1939	1293.3	10	1939	1293.3	20.83
9	-1	1940	1293.6	11	1959	1293.4	22.92
8	-1	1941	1294.3	12	1949	1293.5	25.00
5	-1	1942	1293.8	13	1937	1293.5	27.08
5	-1	1943	1294.2	14	1940	1293.6	29.17
5	-1	1944	1293.9	15	1961	1293.6	31.25
8	-1	1945	1294.4	16	1956	1293.7	33.33
5	-1	1946	1294.1	17	1973	1293.7	35.42
5	-1	1947	1294.4	18	1963	1293.7	37.50
9	-1	1948	1293.9	19	1970	1293.8	39.58
5	-1	1949	1293.5	20	1942	1293.8	41.67
9	-1	1950	1294.5	21	1948	1293.9	43.75
5	-1	1951	1294.4	22	1944	1293.9	45.83
5	-1	1952	1294.1	23	1967	1293.9	47.92
5	-1	1953	1294.2	24	1968	1294.0	50.00
9	-1	1954	1294.7	25	1960	1294.0	52.08
5	-1	1955	1294.1	26	1964	1294.0	54.17
9	-1	1956	1293.7	27	1946	1294.1	56.25
5	-1	1957	1294.1	28	1957	1294.1	58.33
9	-1	1958	1293.0	29	1955	1294.1	60.42
5	-1	1959	1293.4	30	1952	1294.1	62.50
9	-1	1960	1294.0	31	1971	1294.2	64.58
8	-1	1961	1293.6	32	1943	1294.2	66.67
5	-1	1962	1294.4	33	1953	1294.2	68.75
5	-1	1963	1293.7	34	1938	1294.2	70.83
5	-1	1964	1294.0	35	1941	1294.3	72.92
5	-1	1965	1294.6	36	1969	1294.3	75.00
6	-1	1966	1294.9	37	1947	1294.4	77.08
9	-1	1967	1293.9	38	1951	1294.4	79.17
5	-1	1968	1294.0	39	1945	1294.4	81.25
9	-1	1969	1294.3	40	1962	1294.4	83.33
9	-1	1970	1293.8	41	1950	1294.5	85.42
9	-1	1971	1294.2	42	1965	1294.6	87.50
6	-1	1972	1294.7	43	1972	1294.7	89.58
5	-1	1973	1293.7	44	1954	1294.7	91.67
9	-1	1974	1294.8	45	1975	1294.7	93.75
9	-1	1975	1294.7	46	1974	1294.8	95.83
9	-1	1976	1292.9	47	1966	1294.9	97.92

Plate A-50

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- POKEGAMA RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1273.7	1	1938	1276.4	2.08
6	-1	1931	1273.7	2	1950	1276.4	4.17
6	-1	1932	1273.7	3	1953	1276.4	6.25
6	-1	1933	1273.7	4	1965	1276.4	8.33
6	-1	1934	1273.5	5	1966	1276.4	10.42
6	-1	1935	1273.7	6	1969	1276.4	12.50
6	-1	1936	1273.7	7	1975	1276.4	14.58
6	-1	1937	1273.7	8	1948	1276.3	16.67
5	-1	1938	1276.4	9	1971	1276.3	18.75
9	-1	1939	1273.6	10	1972	1276.0	20.83
6	-1	1940	1273.7	11	1954	1275.9	22.92
5	-1	1941	1273.7	12	1943	1275.5	25.00
6	-1	1942	1273.7	13	1944	1275.4	27.08
6	-1	1943	1275.5	14	1952	1275.3	29.17
6	-1	1944	1275.4	15	1974	1274.5	31.25
5	-1	1945	1273.7	16	1945	1273.7	33.33
6	-1	1946	1273.7	17	1946	1273.7	35.42
6	-1	1947	1273.7	18	1947	1273.7	37.50
5	-1	1948	1276.3	19	1937	1273.7	39.58
7	-1	1949	1273.7	20	1949	1273.7	41.67
5	-1	1950	1276.4	21	1931	1273.7	43.75
6	-1	1951	1273.7	22	1951	1273.7	45.83
5	-1	1952	1275.3	23	1941	1273.7	47.92
8	-1	1953	1276.4	24	1932	1273.7	50.00
5	-1	1954	1275.9	25	1940	1273.7	52.08
6	-1	1955	1273.7	26	1955	1273.7	54.17
5	-1	1956	1273.7	27	1956	1273.7	56.25
6	-1	1957	1273.7	28	1957	1273.7	58.33
7	-1	1958	1273.7	29	1958	1273.7	60.42
6	-1	1959	1273.7	30	1959	1273.7	62.50
6	-1	1960	1273.7	31	1960	1273.7	64.58
6	-1	1961	1273.7	32	1961	1273.7	66.67
6	-1	1962	1273.7	33	1962	1273.7	68.75
6	-1	1963	1273.7	34	1963	1273.7	70.83
6	-1	1964	1273.7	35	1964	1273.7	72.92
5	-1	1965	1276.4	36	1933	1273.7	75.00
5	-1	1966	1276.4	37	1967	1273.7	77.08
5	-1	1967	1273.7	38	1968	1273.7	79.17
6	-1	1968	1273.7	39	1935	1273.7	81.25
5	-1	1969	1276.4	40	1970	1273.7	83.33
5	-1	1970	1273.7	41	1930	1273.7	85.42
5	-1	1971	1276.3	42	1973	1273.7	87.50
5	-1	1972	1276.0	43	1942	1273.7	89.58
7	-1	1973	1273.7	44	1936	1273.7	91.67
5	-1	1974	1274.5	45	1976	1273.7	93.75
5	-1	1975	1276.4	46	1939	1273.6	95.83
7	-1	1976	1273.7	47	1934	1273.5	97.92

Plate A-51

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- POKEGAMA RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV.FT.	WEIBULL PLOT POS
8	-1	1930	1272.6	1	1934	1272.1	2.08
5	-1	1931	1272.5	2	1938	1272.1	4.17
9	-1	1932	1272.5	3	1939	1272.1	6.25
9	-1	1933	1272.4	4	1958	1272.2	8.33
9	-1	1934	1272.1	5	1976	1272.3	10.42
5	-1	1935	1272.6	6	1933	1272.4	12.50
8	-1	1936	1272.5	7	1965	1272.4	14.58
5	-1	1937	1272.8	8	1936	1272.5	16.67
8	-1	1938	1272.1	9	1931	1272.5	18.75
5	-1	1939	1272.1	10	1932	1272.5	20.83
5	-1	1940	1272.8	11	1959	1272.5	22.92
8	-1	1941	1273.3	12	1973	1272.5	25.00
5	-1	1942	1272.8	13	1930	1272.6	27.08
5	-1	1943	1272.8	14	1935	1272.6	29.17
5	-1	1944	1272.8	15	1949	1272.7	31.25
5	-1	1945	1273.7	16	1970	1272.8	33.33
5	-1	1946	1272.8	17	1946	1272.8	35.42
5	-1	1947	1272.8	18	1947	1272.8	37.50
6	-1	1948	1273.7	19	1944	1272.8	39.58
5	-1	1949	1272.7	20	1951	1272.8	41.67
7	-1	1950	1273.7	21	1953	1272.8	43.75
5	-1	1951	1272.8	22	1955	1272.8	45.83
6	-1	1952	1273.7	23	1957	1272.8	47.92
5	-1	1953	1272.8	24	1943	1272.8	50.00
6	-1	1954	1273.7	25	1940	1272.8	52.08
5	-1	1955	1272.8	26	1960	1272.8	54.17
5	-1	1956	1273.7	27	1961	1272.8	56.25
5	-1	1957	1272.8	28	1962	1272.8	58.33
5	-1	1958	1272.2	29	1963	1272.8	60.42
5	-1	1959	1272.5	30	1964	1272.8	62.50
5	-1	1960	1272.8	31	1937	1272.8	64.58
5	-1	1961	1272.8	32	1968	1272.8	66.67
5	-1	1962	1272.8	33	1942	1272.8	68.75
5	-1	1963	1272.8	34	1967	1273.2	70.83
5	-1	1964	1272.8	35	1941	1273.3	72.92
7	-1	1965	1272.4	36	1971	1273.5	75.00
7	-1	1966	1273.7	37	1972	1273.6	77.08
8	-1	1967	1273.2	38	1950	1273.7	79.17
5	-1	1968	1272.8	39	1956	1273.7	81.25
6	-1	1969	1273.7	40	1969	1273.7	83.33
9	-1	1970	1272.8	41	1945	1273.7	85.42
9	-1	1971	1273.5	42	1948	1273.7	87.50
9	-1	1972	1273.6	43	1966	1273.7	89.58
5	-1	1973	1272.5	44	1954	1273.7	91.67
7	-1	1974	1273.7	45	1974	1273.7	93.75
6	-1	1975	1273.7	46	1975	1273.7	95.83
5	-1	1976	1272.3	47	1952	1273.7	97.92

Plate A-52

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- SANDY RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1216.6	1	1943	1218.3	2.08
7	-1	1931	1216.6	2	1938	1218.3	4.17
6	-1	1932	1216.6	3	1944	1218.3	6.25
6	-1	1933	1216.5	4	1948	1218.3	8.33
6	-1	1934	1216.6	5	1950	1218.3	10.42
6	-1	1935	1216.6	6	1952	1218.3	12.50
6	-1	1936	1216.6	7	1953	1218.3	14.58
6	-1	1937	1216.6	8	1954	1218.3	16.67
5	-1	1938	1218.3	9	1956	1218.3	18.75
6	-1	1939	1216.6	10	1965	1218.3	20.83
6	-1	1940	1216.6	11	1966	1218.3	22.92
5	-1	1941	1218.1	12	1969	1218.3	25.00
6	-1	1942	1216.6	13	1971	1218.3	27.08
6	-1	1943	1218.3	14	1972	1218.3	29.17
6	-1	1944	1218.3	15	1974	1218.3	31.25
5	-1	1945	1216.7	16	1975	1218.3	33.33
6	-1	1946	1216.6	17	1941	1218.1	35.42
6	-1	1947	1216.6	18	1970	1217.6	37.50
5	-1	1948	1218.3	19	1967	1217.5	39.58
6	-1	1949	1216.6	20	1951	1216.8	41.67
5	-1	1950	1218.3	21	1945	1216.7	43.75
9	-1	1951	1216.8	22	1949	1216.6	45.83
7	-1	1952	1218.3	23	1935	1216.6	47.92
8	-1	1953	1218.3	24	1936	1216.6	50.00
5	-1	1954	1218.3	25	1937	1216.6	52.08
6	-1	1955	1216.6	26	1955	1216.6	54.17
5	-1	1956	1218.3	27	1931	1216.6	56.25
6	-1	1957	1216.6	28	1957	1216.6	58.33
8	-1	1958	1216.6	29	1958	1216.6	60.42
6	-1	1959	1216.6	30	1959	1216.6	62.50
6	-1	1960	1216.6	31	1960	1216.6	64.58
6	-1	1961	1216.5	32	1962	1216.6	66.67
6	-1	1962	1216.6	33	1963	1216.6	68.75
6	-1	1963	1216.6	34	1964	1216.6	70.83
6	-1	1964	1216.6	35	1939	1216.6	72.92
5	-1	1965	1218.3	36	1940	1216.6	75.00
5	-1	1966	1218.3	37	1968	1216.6	77.08
5	-1	1967	1217.5	38	1946	1216.6	79.17
6	-1	1968	1216.6	39	1947	1216.6	81.25
5	-1	1969	1218.3	40	1942	1216.6	83.33
5	-1	1970	1217.6	41	1930	1216.6	85.42
5	-1	1971	1218.3	42	1973	1216.6	87.50
5	-1	1972	1218.3	43	1932	1216.6	89.58
6	-1	1973	1216.6	44	1934	1216.6	91.67
5	-1	1974	1218.3	45	1961	1216.5	93.75
5	-1	1975	1218.3	46	1933	1216.5	95.83
7	-1	1976	1216.3	47	1976	1216.3	97.92

Plate A-[illegible]

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- SANDY RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
9	-1	1930	1215.4	1	1931	1214.9	2.08
5	-1	1931	1214.9	2	1958	1215.0	4.17
9	-1	1932	1216.2	3	1930	1215.4	6.25
5	-1	1933	1215.6	4	1976	1215.5	8.33
9	-1	1934	1215.7	5	1936	1215.6	10.42
5	-1	1935	1216.3	6	1933	1215.6	12.50
9	-1	1936	1215.6	7	1970	1215.7	14.58
9	-1	1937	1216.3	8	1934	1215.7	16.67
9	-1	1938	1216.4	9	1959	1215.8	18.75
5	-1	1939	1216.3	10	1961	1215.9	20.83
9	-1	1940	1216.1	11	1947	1216.1	22.92
6	-1	1941	1216.6	12	1940	1216.1	25.00
5	-1	1942	1216.2	13	1942	1216.2	27.08
5	-1	1943	1216.3	14	1967	1216.2	29.17
5	-1	1944	1216.3	15	1950	1216.2	31.25
6	-1	1945	1216.6	16	1932	1216.2	33.33
5	-1	1946	1216.3	17	1937	1216.3	35.42
9	-1	1947	1216.1	18	1949	1216.3	37.50
9	-1	1948	1216.4	19	1944	1216.3	39.58
5	-1	1949	1216.3	20	1951	1216.3	41.67
9	-1	1950	1216.2	21	1953	1216.3	43.75
5	-1	1951	1216.3	22	1955	1216.3	45.83
6	-1	1952	1216.6	23	1957	1216.3	47.92
5	-1	1953	1216.3	24	1960	1216.3	50.00
6	-1	1954	1216.6	25	1939	1216.3	52.08
5	-1	1955	1216.3	26	1962	1216.3	54.17
9	-1	1956	1216.5	27	1963	1216.3	56.25
5	-1	1957	1216.3	28	1964	1216.3	58.33
5	-1	1958	1215.0	29	1943	1216.3	60.42
5	-1	1959	1215.8	30	1968	1216.3	62.50
5	-1	1960	1216.3	31	1946	1216.3	64.58
9	-1	1961	1215.9	32	1973	1216.3	66.67
5	-1	1962	1216.3	33	1935	1216.3	68.75
5	-1	1963	1216.3	34	1969	1216.4	70.83
5	-1	1964	1216.3	35	1948	1216.4	72.92
8	-1	1965	1216.6	36	1938	1216.4	75.00
7	-1	1966	1216.6	37	1975	1216.4	77.08
9	-1	1967	1216.2	38	1971	1216.5	79.17
5	-1	1968	1216.3	39	1956	1216.5	81.25
9	-1	1969	1216.4	40	1965	1216.6	83.33
9	-1	1970	1215.7	41	1952	1216.6	85.42
9	-1	1971	1216.5	42	1945	1216.6	87.50
7	-1	1972	1216.6	43	1972	1216.6	89.58
5	-1	1973	1216.3	44	1954	1216.6	91.67
7	-1	1974	1216.6	45	1974	1216.6	93.75
9	-1	1975	1216.4	46	1966	1216.6	95.83
9	-1	1976	1215.5	47	1941	1216.6	97.92

Plate A-5[illegible]

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- PINE RESERVOIR ELEVATION

MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1229.6	1	1950	1230.4	2.08
7	-1	1931	1229.6	2	1965	1230.0	4.17
6	-1	1932	1229.2	3	1943	1229.9	6.25
6	-1	1933	1229.6	4	1944	1229.6	8.33
6	-1	1934	1228.3	5	1966	1229.6	10.42
7	-1	1935	1229.6	6	1938	1229.6	12.50
6	-1	1936	1229.6	7	1945	1229.6	14.58
7	-1	1937	1229.6	8	1937	1229.6	16.67
5	-1	1938	1229.6	9	1935	1229.6	18.75
7	-1	1939	1229.5	10	1941	1229.6	20.83
6	-1	1940	1229.5	11	1942	1229.6	22.92
5	-1	1941	1229.6	12	1933	1229.6	25.00
6	-1	1942	1229.6	13	1946	1229.6	27.08
6	-1	1943	1229.9	14	1947	1229.6	29.17
6	-1	1944	1229.6	15	1948	1229.6	31.25
5	-1	1945	1229.6	16	1949	1229.6	33.33
7	-1	1946	1229.6	17	1930	1229.6	35.42
6	-1	1947	1229.6	18	1951	1229.6	37.50
5	-1	1948	1229.6	19	1952	1229.6	39.58
7	-1	1949	1229.6	20	1953	1229.6	41.67
5	-1	1950	1230.4	21	1954	1229.6	43.75
6	-1	1951	1229.6	22	1955	1229.6	45.83
5	-1	1952	1229.6	23	1956	1229.6	47.92
6	-1	1953	1229.6	24	1957	1229.6	50.00
5	-1	1954	1229.6	25	1959	1229.6	52.08
7	-1	1955	1229.6	26	1960	1229.6	54.17
5	-1	1956	1229.6	27	1962	1229.6	56.25
7	-1	1957	1229.6	28	1963	1229.6	58.33
9	-1	1958	1228.9	29	1964	1229.6	60.42
7	-1	1959	1229.6	30	1931	1229.6	62.50
6	-1	1960	1229.6	31	1967	1229.6	64.58
8	-1	1961	1229.3	32	1968	1229.6	66.67
6	-1	1962	1229.6	33	1969	1229.6	68.75
7	-1	1963	1229.6	34	1970	1229.6	70.83
6	-1	1964	1229.6	35	1971	1229.6	72.92
6	-1	1965	1230.0	36	1972	1229.6	75.00
5	-1	1966	1229.6	37	1973	1229.6	77.08
5	-1	1967	1229.6	38	1974	1229.6	79.17
6	-1	1968	1229.6	39	1975	1229.6	81.25
5	-1	1969	1229.6	40	1936	1229.6	83.33
5	-1	1970	1229.6	41	1940	1229.5	85.42
5	-1	1971	1229.6	42	1939	1229.5	87.50
5	-1	1972	1229.6	43	1961	1229.3	89.58
7	-1	1973	1229.6	44	1932	1229.2	91.67
5	-1	1974	1229.6	45	1958	1228.9	93.75
5	-1	1975	1229.6	46	1976	1228.8	95.83
7	-1	1976	1228.8	47	1934	1228.3	97.92

Plate A-[illegible]

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- PINE RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
5	-1	1930	1228.9	1	1934	1227.6	2.08
5	-1	1931	1228.1	2	1976	1227.9	4.17
5	-1	1932	1228.6	3	1958	1228.0	6.25
5	-1	1933	1228.7	4	1931	1228.1	8.33
9	-1	1934	1227.6	5	1959	1228.6	10.42
5	-1	1935	1228.8	6	1932	1228.6	12.50
9	-1	1936	1228.7	7	1955	1228.6	14.58
5	-1	1937	1228.9	8	1936	1228.7	16.67
8	-1	1938	1229.5	9	1939	1228.7	18.75
5	-1	1939	1228.7	10	1933	1228.7	20.83
5	-1	1940	1228.9	11	1961	1228.7	22.92
5	-1	1941	1229.6	12	1946	1228.8	25.00
5	-1	1942	1228.9	13	1935	1228.8	27.08
5	-1	1943	1228.9	14	1963	1228.8	29.17
5	-1	1944	1228.9	15	1930	1228.9	31.25
6	-1	1945	1229.6	16	1949	1228.9	33.33
5	-1	1946	1228.8	17	1937	1228.9	35.42
5	-1	1947	1228.9	18	1957	1228.9	37.50
5	-1	1948	1229.6	19	1940	1228.9	39.58
5	-1	1949	1228.9	20	1973	1228.9	41.67
7	-1	1950	1229.6	21	1951	1228.9	43.75
5	-1	1951	1228.9	22	1953	1228.9	45.83
5	-1	1952	1229.6	23	1947	1228.9	47.92
5	-1	1953	1228.9	24	1942	1228.9	50.00
5	-1	1954	1229.6	25	1944	1228.9	52.08
5	-1	1955	1228.6	26	1960	1228.9	54.17
9	-1	1956	1229.5	27	1962	1228.9	56.25
5	-1	1957	1228.9	28	1943	1228.9	58.33
5	-1	1958	1228.0	29	1964	1228.9	60.42
5	-1	1959	1228.6	30	1968	1228.9	62.50
5	-1	1960	1228.9	31	1970	1229.0	64.58
5	-1	1961	1228.7	32	1967	1229.4	66.67
5	-1	1962	1228.9	33	1969	1229.5	68.75
5	-1	1963	1228.8	34	1956	1229.5	70.83
5	-1	1964	1228.9	35	1938	1229.5	72.92
5	-1	1965	1229.6	36	1965	1229.6	75.00
6	-1	1966	1229.6	37	1966	1229.6	77.08
9	-1	1967	1229.4	38	1948	1229.6	79.17
5	-1	1968	1228.9	39	1954	1229.6	81.25
8	-1	1969	1229.5	40	1952	1229.6	83.33
9	-1	1970	1229.0	41	1941	1229.6	85.42
5	-1	1971	1229.6	42	1971	1229.6	87.50
5	-1	1972	1229.6	43	1972	1229.6	89.58
5	-1	1973	1228.9	44	1945	1229.6	91.67
5	-1	1974	1229.6	45	1974	1229.6	93.75
5	-1	1975	1229.6	46	1975	1229.6	95.83
9	-1	1976	1227.9	47	1950	1229.6	97.92

Plate A-[illegible]6

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- GULL RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
6	-1	1930	1194.0	1	1950	1194.8	2.08
7	-1	1931	1193.9	2	1938	1194.5	4.17
6	-1	1932	1193.5	3	1944	1194.4	6.25
6	-1	1933	1194.0	4	1975	1194.3	8.33
5	-1	1934	1193.0	5	1965	1194.2	10.42
7	-1	1935	1194.0	6	1943	1194.1	12.50
6	-1	1936	1193.9	7	1952	1194.1	14.58
6	-1	1937	1194.0	8	1937	1194.0	16.67
5	-1	1938	1194.5	9	1941	1194.0	18.75
7	-1	1939	1193.9	10	1942	1194.0	20.83
6	-1	1940	1193.8	11	1935	1194.0	22.92
5	-1	1941	1194.0	12	1945	1194.0	25.00
6	-1	1942	1194.0	13	1946	1194.0	27.08
6	-1	1943	1194.1	14	1947	1194.0	29.17
6	-1	1944	1194.4	15	1948	1194.0	31.25
5	-1	1945	1194.0	16	1949	1194.0	33.33
7	-1	1946	1194.0	17	1951	1194.0	35.42
6	-1	1947	1194.0	18	1953	1194.0	37.50
5	-1	1948	1194.0	19	1954	1194.0	39.58
6	-1	1949	1194.0	20	1955	1194.0	41.67
5	-1	1950	1194.8	21	1956	1194.0	43.75
6	-1	1951	1194.0	22	1957	1194.0	45.83
7	-1	1952	1194.1	23	1958	1194.0	47.92
6	-1	1953	1194.0	24	1959	1194.0	50.00
5	-1	1954	1194.0	25	1960	1194.0	52.08
8	-1	1955	1194.0	26	1962	1194.0	54.17
5	-1	1956	1194.0	27	1963	1194.0	56.25
7	-1	1957	1194.0	28	1964	1194.0	58.33
8	-1	1958	1194.0	29	1966	1194.0	60.42
6	-1	1959	1194.0	30	1967	1194.0	62.50
6	-1	1960	1194.0	31	1968	1194.0	64.58
8	-1	1961	1193.6	32	1969	1194.0	66.67
6	-1	1962	1194.0	33	1970	1194.0	68.75
9	-1	1963	1194.0	34	1971	1194.0	70.83
9	-1	1964	1194.0	35	1972	1194.0	72.92
6	-1	1965	1194.2	36	1973	1194.0	75.00
5	-1	1966	1194.0	37	1974	1194.0	77.08
5	-1	1967	1194.0	38	1933	1194.0	79.17
7	-1	1968	1194.0	39	1930	1194.0	81.25
5	-1	1969	1194.0	40	1939	1193.9	83.33
5	-1	1970	1194.0	41	1931	1193.9	85.42
5	-1	1971	1194.0	42	1936	1193.9	87.50
5	-1	1972	1194.0	43	1940	1193.8	89.58
6	-1	1973	1194.0	44	1961	1193.6	91.67
5	-1	1974	1194.0	45	1932	1193.5	93.75
5	-1	1975	1194.3	46	1976	1193.5	95.83
7	-1	1976	1193.5	47	1934	1193.0	97.92

Plate A-57

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- GULL RESERVOIR ELEVATION

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	ELEV,FT.	RANK	WATER YEAR	ELEV,FT.	WEIBULL PLOT POS
9	-1	1930	1193.0	1	1934	1192.5	2.08
5	-1	1931	1193.0	2	1976	1192.6	4.17
9	-1	1932	1192.6	3	1932	1192.6	6.25
9	-1	1933	1193.1	4	1936	1192.9	8.33
9	-1	1934	1192.5	5	1931	1193.0	10.42
5	-1	1935	1193.5	6	1930	1193.0	12.50
9	-1	1936	1192.9	7	1933	1193.1	14.58
5	-1	1937	1193.6	8	1955	1193.4	16.67
8	-1	1938	1193.9	9	1958	1193.4	18.75
5	-1	1939	1193.4	10	1939	1193.4	20.83
5	-1	1940	1193.6	11	1970	1193.5	22.92
7	-1	1941	1193.9	12	1935	1193.5	25.00
5	-1	1942	1193.6	13	1961	1193.5	27.08
5	-1	1943	1193.6	14	1964	1193.5	29.17
5	-1	1944	1193.6	15	1963	1193.5	31.25
6	-1	1945	1194.0	16	1968	1193.5	33.33
5	-1	1946	1193.6	17	1959	1193.6	35.42
5	-1	1947	1193.9	18	1957	1193.6	37.50
6	-1	1948	1193.9	19	1940	1193.6	39.58
5	-1	1949	1193.6	20	1946	1193.6	41.67
9	-1	1950	1193.7	21	1949	1193.6	43.75
5	-1	1951	1193.6	22	1969	1193.6	45.83
9	-1	1952	1194.0	23	1953	1193.6	47.92
5	-1	1953	1193.6	24	1937	1193.6	50.00
5	-1	1954	1194.0	25	1960	1193.6	52.08
5	-1	1955	1193.4	26	1942	1193.6	54.17
9	-1	1956	1193.9	27	1962	1193.6	56.25
5	-1	1957	1193.6	28	1944	1193.6	58.33
5	-1	1958	1193.4	29	1943	1193.6	60.42
5	-1	1959	1193.6	30	1951	1193.6	62.50
5	-1	1960	1193.6	31	1973	1193.6	64.58
5	-1	1961	1193.5	32	1950	1193.7	66.67
5	-1	1962	1193.6	33	1967	1193.8	68.75
5	-1	1963	1193.5	34	1948	1193.9	70.83
5	-1	1964	1193.5	35	1956	1193.9	72.92
8	-1	1965	1194.0	36	1947	1193.9	75.00
9	-1	1966	1193.9	37	1938	1193.9	77.08
9	-1	1967	1193.8	38	1974	1193.9	79.17
5	-1	1968	1193.5	39	1966	1193.9	81.25
9	-1	1969	1193.6	40	1941	1193.9	83.33
9	-1	1970	1193.5	41	1971	1194.0	85.42
9	-1	1971	1194.0	42	1965	1194.0	87.50
5	-1	1972	1194.0	43	1945	1194.0	89.58
5	-1	1973	1193.6	44	1952	1194.0	91.67
9	-1	1974	1193.9	45	1972	1194.0	93.75
6	-1	1975	1194.0	46	1975	1194.0	95.83
9	-1	1976	1192.6	47	1954	1194.0	97.92

Plate A-58

- ANALYSIS OF MAXIMUMS -

-PLOTTING POSITIONS- AITKIN FLOW

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
5	-1	1930	3329.	1	1950	21595.	2.08
6	-1	1931	2474.	2	1975	20217.	4.17
5	-1	1932	2950.	3	1969	16309.	6.25
5	-1	1933	2757.	4	1948	14723.	8.33
4	-1	1934	1984.	5	1965	13688.	10.42
5	-1	1935	3028.	6	1966	13118.	12.50
5	-1	1936	5003.	7	1971	13048.	14.58
5	-1	1937	4031.	8	1953	12249.	16.67
5	-1	1938	11150.	9	1952	11428.	18.75
4	-1	1939	5648.	10	1956	11326.	20.83
5	-1	1940	3422.	11	1938	11150.	22.92
4	-1	1941	10543.	12	1972	11047.	25.00
5	-1	1942	4843.	13	1944	10881.	27.08
6	-1	1943	10641.	14	1954	10760.	29.17
6	-1	1944	10881.	15	1943	10641.	31.25
3	-1	1945	10531.	16	1974	10633.	33.33
6	-1	1946	5688.	17	1941	10543.	35.42
4	-1	1947	6589.	18	1945	10531.	37.50
5	-1	1948	14723.	19	1970	9777.	39.58
7	-1	1949	5590.	20	1967	9203.	41.67
5	-1	1950	21595.	21	1962	7793.	43.75
5	-1	1951	7442.	22	1973	7763.	45.83
7	-1	1952	11428.	23	1951	7442.	47.92
8	-1	1953	12249.	24	1947	6589.	50.00
5	-1	1954	10760.	25	1964	6208.	52.08
4	-1	1955	4693.	26	1946	5688.	54.17
4	-1	1956	11326.	27	1939	5648.	56.25
4	-1	1957	5296.	28	1949	5590.	58.33
2	-1	1958	2182.	29	1976	5325.	60.42
6	-1	1959	3794.	30	1957	5296.	62.50
5	-1	1960	5193.	31	1960	5193.	64.58
5	-1	1961	3246.	32	1968	5037.	66.67
5	-1	1962	7793.	33	1936	5003.	68.75
6	-1	1963	4693.	34	1942	4843.	70.83
5	-1	1964	6208.	35	1955	4693.	72.92
4	-1	1965	13688.	36	1963	4693.	75.00
5	-1	1966	13118.	37	1937	4031.	77.08
4	-1	1967	9203.	38	1959	3794.	79.17
6	-1	1968	5037.	39	1940	3422.	81.25
4	-1	1969	16309.	40	1930	3329.	83.33
5	-1	1970	9777.	41	1961	3246.	85.42
4	-1	1971	13048.	42	1935	3028.	87.50
4	-1	1972	11047.	43	1932	2950.	89.58
10	-1	1973	7763.	44	1933	2757.	91.67
6	-1	1974	10633.	45	1931	2474.	93.75
5	-1	1975	20217.	46	1958	2182.	95.83
4	-1	1976	5325.	47	1934	1984.	97.92

Plate A-59

- ANALYSIS OF MINIMUMS -

-PLOTTING POSITIONS- ANOKA FLOW

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
8	-1	1930	1052.	1	1934	810.	2.08
9	-1	1931	1347.	2	1936	827.	4.17
10	-1	1932	1263.	3	1933	972.	6.25
9	-1	1933	972.	4	1935	1030.	8.33
8	-1	1934	810.	5	1976	1048.	10.42
1	-1	1935	1030.	6	1930	1052.	12.50
7	-1	1936	827.	7	1932	1263.	14.58
2	-1	1937	1373.	8	1931	1347.	16.67
1	-1	1938	2061.	9	1940	1371.	18.75
10	-1	1939	1901.	10	1937	1373.	20.83
9	-1	1940	1371.	11	1961	1642.	22.92
8	-1	1941	2827.	12	1970	1858.	25.00
1	-1	1942	3568.	13	1939	1901.	27.08
9	-1	1943	4007.	14	1960	1977.	29.17
1	-1	1944	4349.	15	1938	2061.	31.25
1	-1	1945	4275.	16	1948	2067.	33.33
9	-1	1946	3625.	17	1967	2219.	35.42
8	-1	1947	3074.	18	1959	2398.	37.50
10	-1	1948	2067.	19	1962	2449.	39.58
9	-1	1949	2560.	20	1969	2486.	41.67
11	-1	1950	3466.	21	1958	2530.	43.75
1	-1	1951	4115.	22	1949	2560.	45.83
11	-1	1952	3945.	23	1964	2571.	47.92
1	-1	1953	4831.	24	1956	2584.	50.00
12	-1	1954	4178.	25	1963	2822.	52.08
11	-1	1955	3120.	26	1941	2827.	54.17
10	-1	1956	2584.	27	1957	3060.	56.25
1	-1	1957	3060.	28	1947	3074.	58.33
8	-1	1958	2530.	29	1965	3090.	60.42
2	-1	1959	2398.	30	1955	3120.	62.50
8	-1	1960	1977.	31	1971	3126.	64.58
8	-1	1961	1642.	32	1968	3190.	66.67
3	-1	1962	2449.	33	1974	3204.	68.75
11	-1	1963	2822.	34	1950	3466.	70.83
8	-1	1964	2571.	35	1942	3568.	72.92
3	-1	1965	3090.	36	1946	3625.	75.00
12	-1	1966	4976.	37	1952	3945.	77.08
11	-1	1967	2219.	38	1943	4007.	79.17
1	-1	1968	3190.	39	1951	4115.	81.25
9	-1	1969	2486.	40	1954	4178.	83.33
9	-1	1970	1858.	41	1975	4235.	85.42
9	-1	1971	3126.	42	1945	4275.	87.50
12	-1	1972	6905.	43	1944	4349.	89.58
7	-1	1973	4609.	44	1973	4609.	91.67
9	-1	1974	3204.	45	1953	4831.	93.75
8	-1	1975	4235.	46	1966	4976.	95.83
9	-1	1976	1048.	47	1972	6905.	97.92

Plate A-60

PROBLEM 2

BANK EROSION CONTROL ON SIX MISSISSIPPI RIVER HEADWATERS LAKES

BACKGROUND

Bank erosion caused by higher than normal levels in the six headwaters lakes causes destruction of shoreline archeological and cultural sites; damages recreation, residential, and commercial interests; and contributes to degraded water quality. Erosion produces a progressive loss and deterioration of lakeshore lands and related vegetation. Bank erosion and subsequent wave action have produced sandbars which have closed off northern pike spawning marshes in the Pine River Lakes (Whitefish Chain of Lakes).

Erosion in the six headwaters lakes has varied through the years since the six controlling dams were first built in the late 1800's and early 1900's. The most notable erosion problems around each of the six lakes are found where natural banks are high and the process of natural stabilization is not completed. Erosion was more severe before the 1930's when each of the lakes was subject to greater fluctuations under different operating plans. Erosion was also more severe during extended periods of high water such as during the early 1950's.

Existing shoreline erosion around the six Mississippi River Headwaters Lakes is the most serious on Winnibigoshish, Leech, and Sandy Lakes. Winnibigoshish and Leech Lakes have a much larger surface area than the other four lakes. Because of their large size, they are more difficult to control and more susceptible to adverse effects of wind and wave action. Sandy Lake, although only slightly larger than Pokegama Lake and half as large as Pine River Lakes, also experiences considerable shoreline erosion. The circular shoreline configuration of Sandy Lake and the 8-foot range of possible lake level fluctuations are principal causes of the erosion.

Current shoreline erosion on Pokegama, Pine River, and Gull Lakes is not as significant as on the other three lakes. The shoreline configuration on Pokegama Lake (somewhat star-shaped) plus more rocky shoreline areas limits erosion losses there. Pine River and Gull Lakes experience less erosion because peak inflows to these lakes are not as variable, and the lakes can more easily be maintained within desirable operating limits year-round and from year to year.

Most of the erosion occurs on lands not owned by the Corps of Engineers but for which the Corps has flowage easements. (Fee ownership amounts to over 1,800 acres, while flowage easements cover almost 300,000 acres.) Some erosion control projects have been developed by the U.S. Forest Service and by private interests around Lake Winnibigoshish. The St. Paul District has a small erosion control project under design at the Winnibigoshish Lake damsite. The erosion sites need to be identified and a practical plan of approach needs to be developed to arrest and control erosion, if possible.

GEOLOGY AND SOILS

The geology and soils background information for the lake erosion problem is identical to that presented earlier for the optimum lake operating problem (see page A-3).

HYDROLOGY AND HYDRAULIC STUDIES

High water elevation-frequency curves were first developed for each of the six headwaters lakes and Sandy Lake tail water for the 1936-1976 period of record and for present conditions (plates A-54 through A-60). The 1930-1935 years were not included in the analysis because the drought years recorded during the early 1930's would unduly influence the high water-frequency curves. Another reason for not including the years prior to 1936 is that the current lake operating plans were changed in 1936.

A typical riprap design was then developed for each of the six headwaters lakes using the criteria shown in the following two tables. These criteria generally would be suitable for embankment or dam design.

Mississippi River Headwaters Lakes data

Item	Winnibigoshish	Leech	Pokegama	Sandy	Pine River	Gull
Maximum observed lake elevation (feet) 1929 adj. (1936-1976)	1303.17	1297.07	1277.89	1224.82	1231.98	1195.09
100-year flood elevation (feet) 1929 adj. (1936-1976)	1302.90	1297.0	1277.9	1223.9	1232.8	1195.4
Estimated typical effective fetch (miles)	11	12	2	2	3	4
Design overland wind velocity (mph)	40	40	40	40	40	40
Design ratio of overwater winds to overland winds	1.3	1.3	1.21	1.21	1.26	1.28
Design overwater wind velocity (mph)	52	52	48	48	50	51
Wind duration (hours)	1.0(1)	1.0(1)	0.47	0.47	0.63	0.77
Maximum wave height (feet) based on figure 5-5, EM 1110-2-2300	5.2	5.2	2.9	2.9	4.0	4.8
Design still water level (feet) 1929 adj.	1302.90	1297.0	1277.9	1223.90	1232.80	1195.4
Wave height (feet), H_s, equal to the average of the highest 1/3 of all waves for this design condition	5.2	5.2	2.9	2.9	3.8	4.3
Wave runup (feet) plus wind tide rise (vertical feet) for the average of the highest 1/3 of all waves for this design condition	7.9	7.9	3.7	3.7	5.1	6.1

(1) Wind duration was assumed to not exceed 1 hour.

Item	Winnibigoshish	Leech	Pokegama	Sandy	Pine River	Gull
Slope of proposed riprap embankment (feet per foot)	2.50	2.50	2.50	2.50	2.50	2.50
Specific gravity of rock	2.64	2.64	2.64	2.64	2.64	2.64
Riprap layer thickness (feet) required for design conditions, based on figure 5-6, EM 1110-2-2300	24	24	15	15	15	15
Required median rock size, Wa (pounds)	220	220	70	70	140	140
Required maximum rock size, W max (pounds)	880	880	280	280	560	760
Required minimum rock size, W min (pounds)	28	28	9	9	18	24
Recommended top of riprap elevation (feet) 1929 adjustment(1)	1310.80	1304.90	1281.60	1227.60	1237.90	1201.50
Recommended bottom of riprap elevation (feet) adj.(2)	1291.94	1288.20	1265.40	1209.30	1221.30	1187.80

Mississippi River Headwaters Lakes - Preliminary riprap design

(1) The recommended top of riprap elevation is equal to the point of maximum wave runup.

(2) The recommended bottom of riprap elevation is 5 feet below the present minimum ordinary operating limit.

The proposed design shown in the preceding table was further modified to more adequately reflect the difference between protection for headwaters dams and protection for bank erosion. Shoreline banks should not have to meet the same design criteria as those used for dams. Therefore, required shoreline protection was estimated to protect against a 100-year lake elevation, or maximum observed lake elevation, and at the same time provide a minimum of 3 feet of freeboard for wave runoff to prevent undermining. The riprap would be carried only to the maximum elevation of the property where the elevation of the property was less than the maximum design elevation in situations where the protected property or developments were at an elevation less than the desired protection level. The following table summarizes the design elevations used for the top and bottom elevations of riprap for shoreline protection estimate.

Erosion protection on the Mississippi River Headwaters Lakes - elevations and riprap designs

Lake	Elevation, top of riprap	Approximate 20 May 1976 level	20 May 1976 level minus 3 feet	Calendar year 1976 low	Current minimum operating limit	Selected: Bottom of riprap elevation	Selected: Total vertical depth (feet)
Winnibigoshish	1306.5	1297.6	1294.6	1297	1294.94	1294.5	12
Leech	1300	1293.9	1290.9	1292.7	1292.7	1290.5	9.5
Pokegama	1281	1273.3	1270.3	1272.4	1270.42	1270.0	11.0
Sandy	1228	1216.2	1213.2	1214.9	1214.31	1213.0	15
Pine River	1237.5	1228.8	1225.8	1227.7	1225.32	1225.0	12.5
Gull	1198	1193.6	1190.6	1192.5	1192.75	1190.5	7.5

For each of the six headwaters lakes, the total length of erodible shoreline was estimated in two categories: (1) existing erosion and (2) potential erosion. Existing erosion estimates for the six headwaters lakes were obtained through observations taken by boat in 1977 (plates A-61 through A-66). Potential erosion lengths for developed or developable properties were derived from flood damage surveys on Sandy and Pokegama Lakes and from erosion surveys taken by the U.S. Forest Service on Winnibigoshish Lake. Potential erosion values for developed or developable properties on the remaining three lakes (Leech, Pine River, and Gull) were developed using correlations with the three surveyed lakes. Potential shoreline erosion areas for each of the six lakes were assumed to include all properties that had onshore slopes greater than 5 percent.

An attempt was made to estimate the current annual cost of existing and potential shoreline erosion. Although no precise figures exist on the number of square feet of shoreline eroded on each of the headwaters lakes, the U.S. Forest Service has made detailed studies of the losses at Winnibigoshish Lake. These studies indicate that losses vary considerably from one location to another but, at a minimum, losses average about 1 foot of depth per foot of shoreline annually. An estimated dollar value per square foot of property was derived for each of the six headwaters lakes using local assessors' knowledge of recent sales estimates for the value of lakefront property (based on shoreline front footage) and average lot depth. The following table summarizes estimated erosion costs based on an erosion rate of 1 foot of depth per foot of shoreline and on the present length of eroding shoreline.

Estimated erosion costs[1]

Lake	Present shoreline erosion (feet)	Value per front square foot	Annual value of lost shoreline
Winnibigoshish	54,250	$0.11	$5,950
Leech	27,500	0.27	7,400
Pokegama	1,450	0.58	850
Sandy	29,600	0.54	16,000
Pine River	3,610	0.84	3,050
Gull	1,000	0.87	850
Total	117,410		34,100

(1) Indexed from October 1977 to October 1981 levels.

The following table compares present lakeshore erosion under the existing plan of lake operation and potential erosion with a lake operating plan using higher water levels.

Existing and potential erosion

Lake	Total shoreline[1]		Present erosion (feet)	Potential erosion	
	Miles	Feet		To developed properties (feet)	To all shoreline properties[2] (feet)
Winnibigoshish	35.0	184,800	54,250	79,200	114,800
Leech	182.3	962,550	27,500	34,000	808,550
Pokegama	50.8	268,200	1,450	55,100	147,600
Sandy	56.5	298,300	29,600	42,100	293,000
Pine River	106.0	559,680	3,610	112,000	498,700
Gull	35.6	188,000	1,000	100,000	170,000
Total	466.2	2,461,530	117,410	422,400	2,032,650

(1) Figures are for the lake proper and are from the 1967 Minnesota Department of Natural Resources Shoreline Management Study.
(2) Potential erosion values include all onshore land slopes greater than 5 percent and the present erosion and developed property value shown.

Existing erosion estimates for the six headwaters lakes were obtained through observations taken by boat. Figures for potential erosion to developed properties were derived from flood damage surveys on Sandy and Pokegama Lakes and from erosion surveys by the U.S. Forest Service on Winnibigoshish Lake. Potential erosion values for developed properties on Leech, Pine River, and Gull Lakes were derived using correlations with the three surveyed lakes. Potential shoreline erosion to all areas for each of the six lakes was assumed to include all properties that had onshore slopes greater than 5 percent.

COST ESTIMATE

No economically feasible project exists for protecting large expanses of lake shoreline by structural means. The least cost method would be the natural method currently used by the U.S. Forest Service on Winnibigoshish Lake. The method involves placing ungraded gravel, up to 6 inches in diameter, on eroding shoreline slopes. Approximately 1 cubic yard of riprap is placed on each foot of shoreline at a cost of about $8 per foot. This method appears to be effective only on banks that have less than 10 percent slope, and the cost is still too great to make it economically feasible. The following table of costs and benefits for natural shoreline protection is included for reference only.

Natural method of shoreline protection

Lake	Potential damage area requiring protection(1) (feet)	Protection first cost(2)	Protection annual cost(3)	Annual value of shoreline lost (per foot)	Total annual value of lost shoreline
Winnibigoshish	79,200	$849,000	$64,800	0.11	$8,700
Leech	34,000	364,500	27,800	0.27	9,200
Pokegama	55,100	590,700	45,100	0.58	31,950
Sandy	42,100	451,300	34,400	0.54	22,750
Pine River	112,000	1,200,600	91,600	0.84	94,100
Gull	100,000	1,072,000	81,800	0.87	87,000
Total	422,400	4,528,100	345,500		253,700

Benefit-cost ratio = $\frac{\$253,700}{\$345,500} = 0.73$

(1) Derived from 1965 U.S. Forest Service shoreline survey and 1977 St. Paul District damage surveys. Includes only developed or potentially developable properties.

(2) $8 per foot of shoreline.

(3) Based on 100-year project life and 7 5/8-percent interest rate. No operation and maintenance costs are included.

RECOMMENDED ACTION

No structural improvements or changes in lake operation are recommended to protect large expanses of shoreline, although protection of individual properties may be justified. The current plan of operation for the six headwaters lakes has stabilized or caused a decline in erosion on each of the six lakes. Recent detailed studies of erosion on Winnibigoshish Lake present a good example of the erosion decline as summarized in the following conclusions for the period 1939 to 1969.

a. Fifty-six percent of the total erosion could have occurred during only 3 years (1943, 1944, and 1950).

b. Approximately two-thirds of the total erosion occurred in the first 12 years of the period 1939-1969.

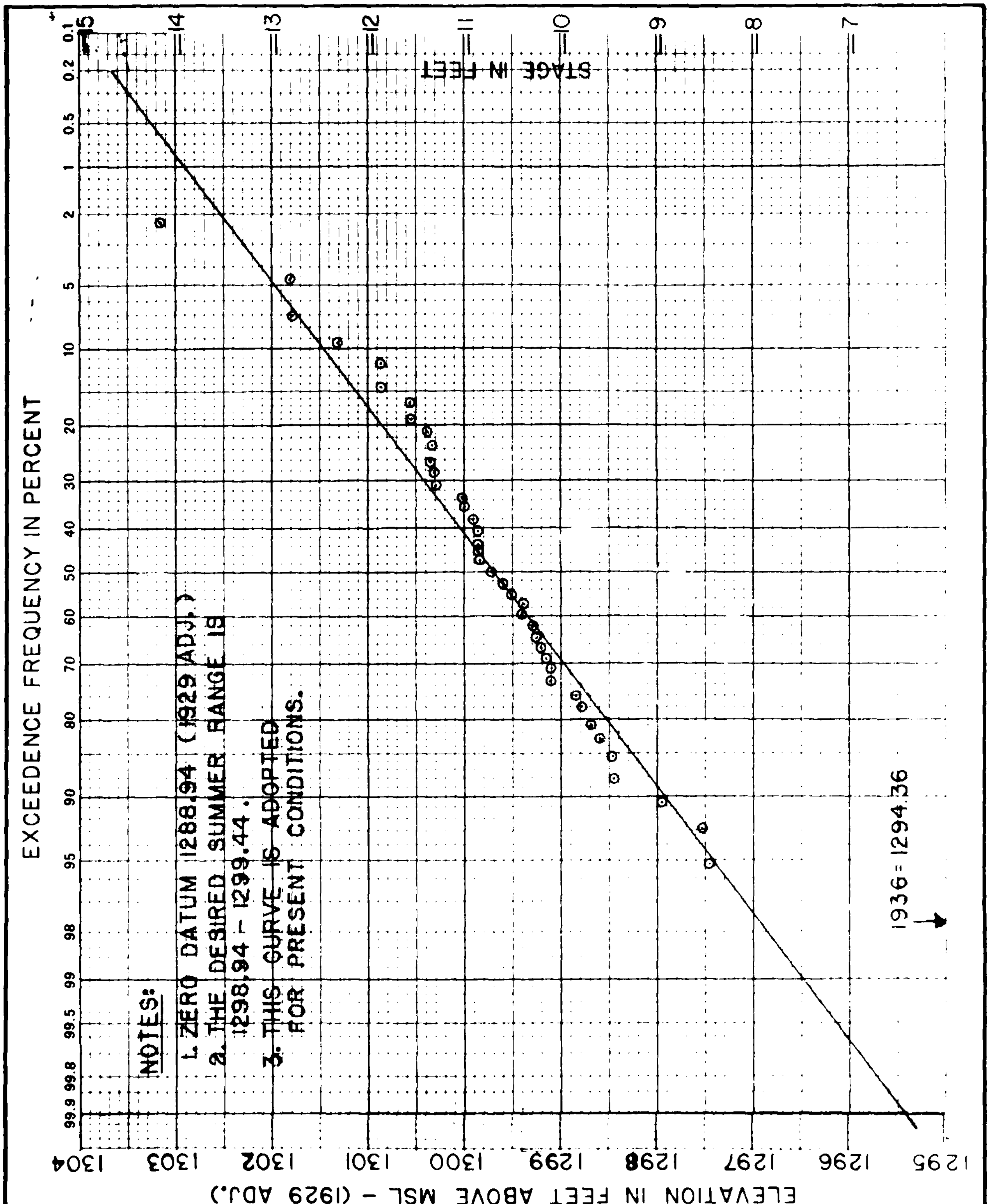
c. There was an overall decline in potential erosion.

A change in the normal summer operating plan for Winnibigoshish Lake is currently being tried as a result of a 1975 request from the Governor of Minnesota. Under the new experimental plan, the level of Winnibigoshish Lake is 1 foot lower than the previous summer operating plan level. This is being done because people living around the lake, people with businesses on the lake, and Forest Service officials are all concerned with reducing the shore damage and erosion taking place. The trial summer level reduction experiment started in 1976 and will be in effect for about 5 years.

No further studies of bank erosion control measures are recommended under the Mississippi River Headwaters study authority. Existing and potential erosion at individual archeological sites will be addressed further under the District's operation and maintenance authority.

PLATE SUMMARY

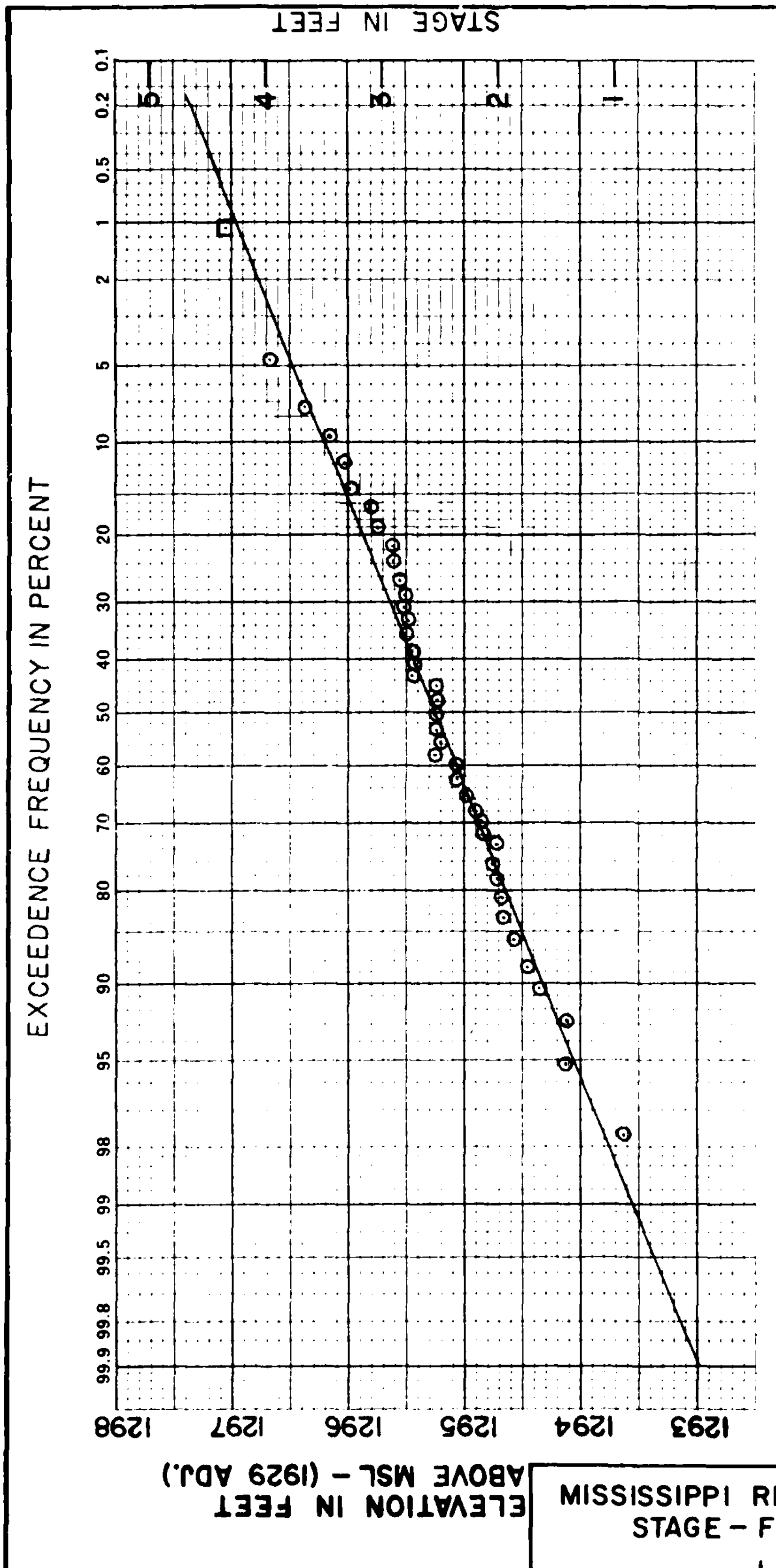
Number	Item
A-61 - A-67	Elevation-frequency curves for each of the six lakes and Sandy Lake tail water.
A-68 - A-73	Shoreline erosion location curves for each of the six lakes.



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE - FREQUENCY ANALYSIS

WINNIBIGOSHISH LAKE
1936 - 1976

ST. PAUL DISTRICT CORPS OF ENGINEERS



NOTES:

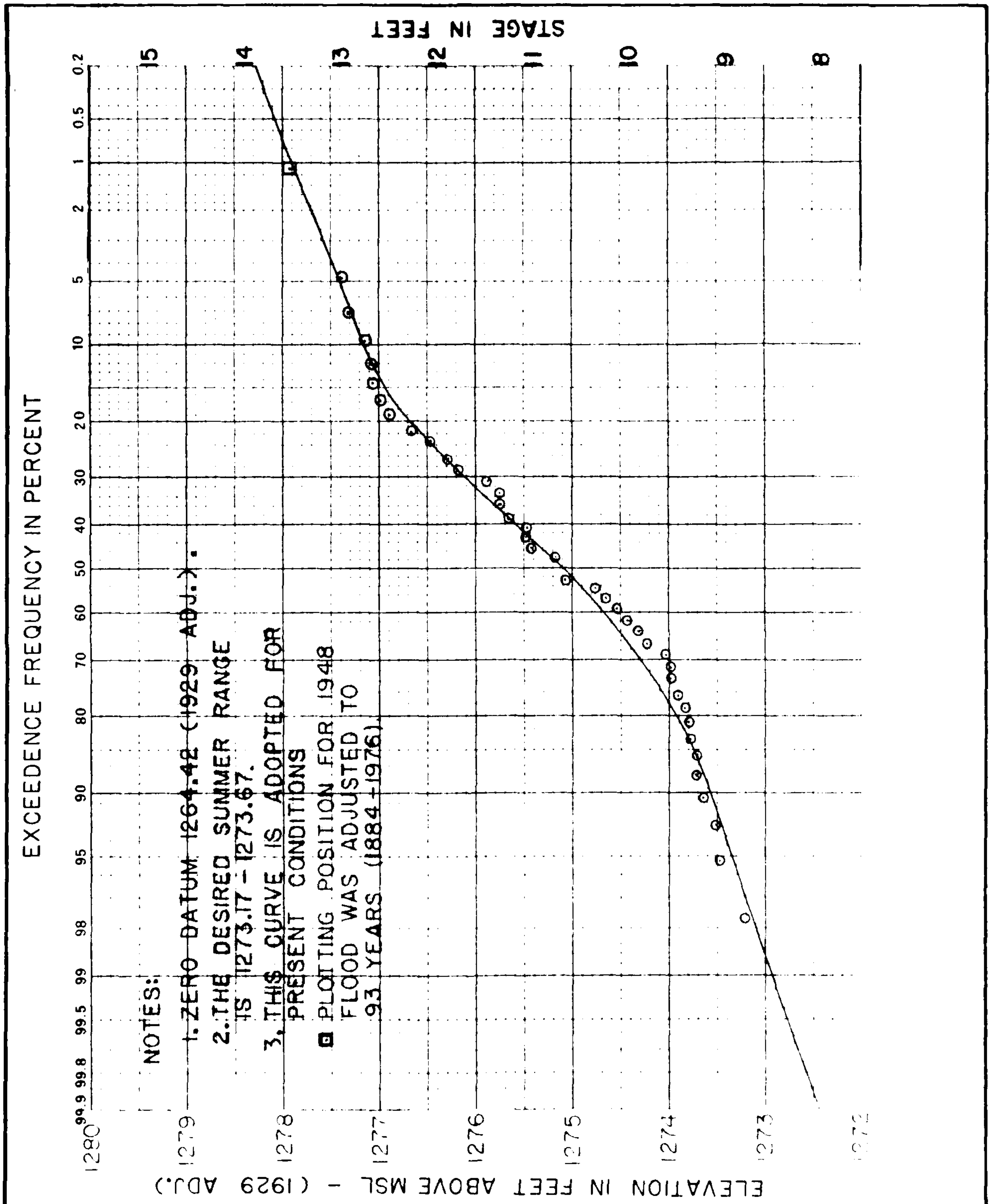
1. ZERO DATUM 1292.70 (1929 ADJ.).
2. THE DESIRED SUMMER RANGE IS 1294.50 – 1294.90.
3. THIS CURVE IS ADOPTED FOR PRESENT CONDITIONS.

⊡ PLOTTING POSITION FOR 1950 FLOOD WAS ADJUSTED TO 92 YEARS (1885–1976).

MISSISSIPPI RIVER HEADWATERS STUDY
STAGE – FREQUENCY ANALYSIS

LEECH LAKE
1936 – 1976

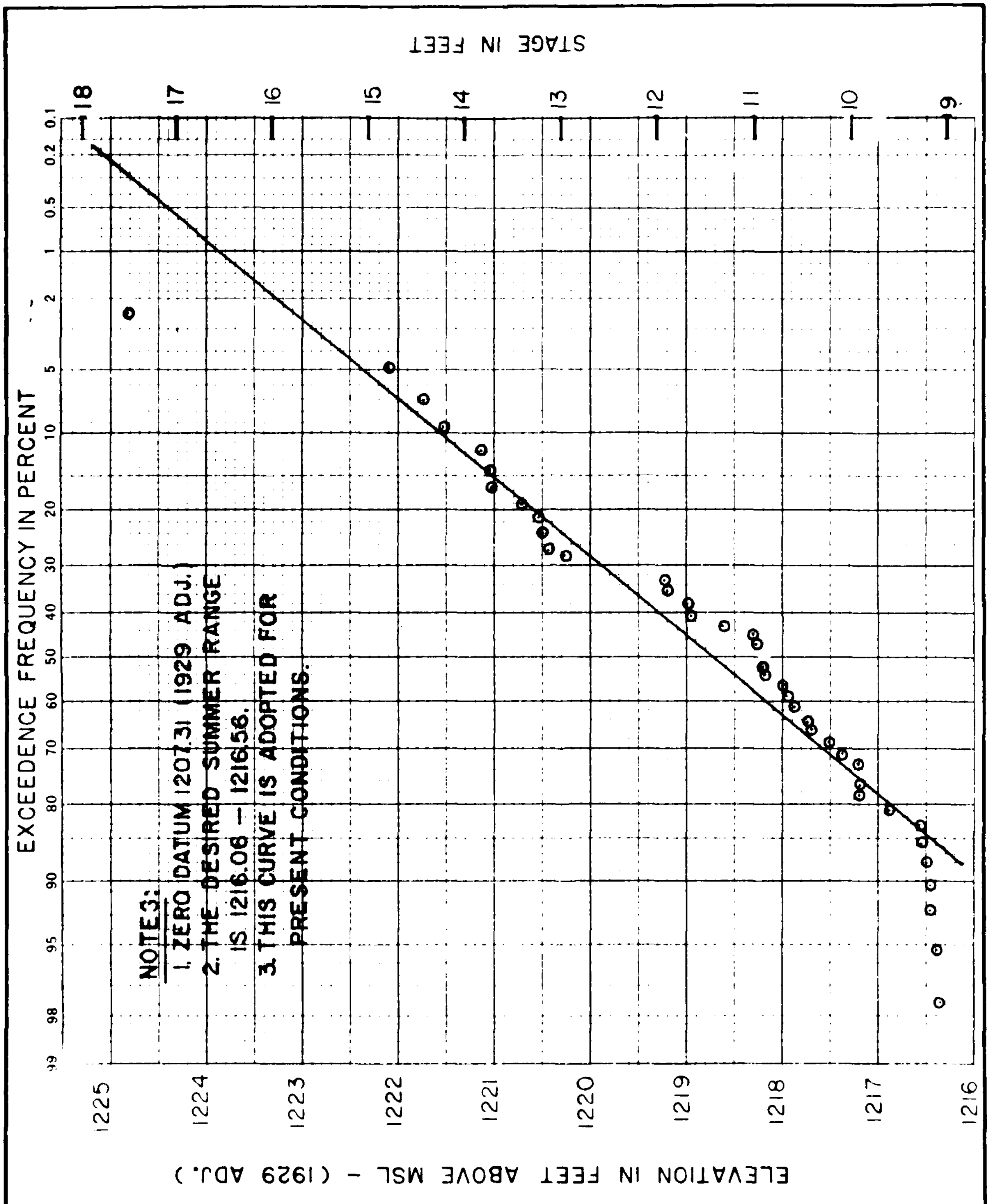
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE - FREQUENCY ANALYSIS

POKEGAMA LAKE
1936 - 1976

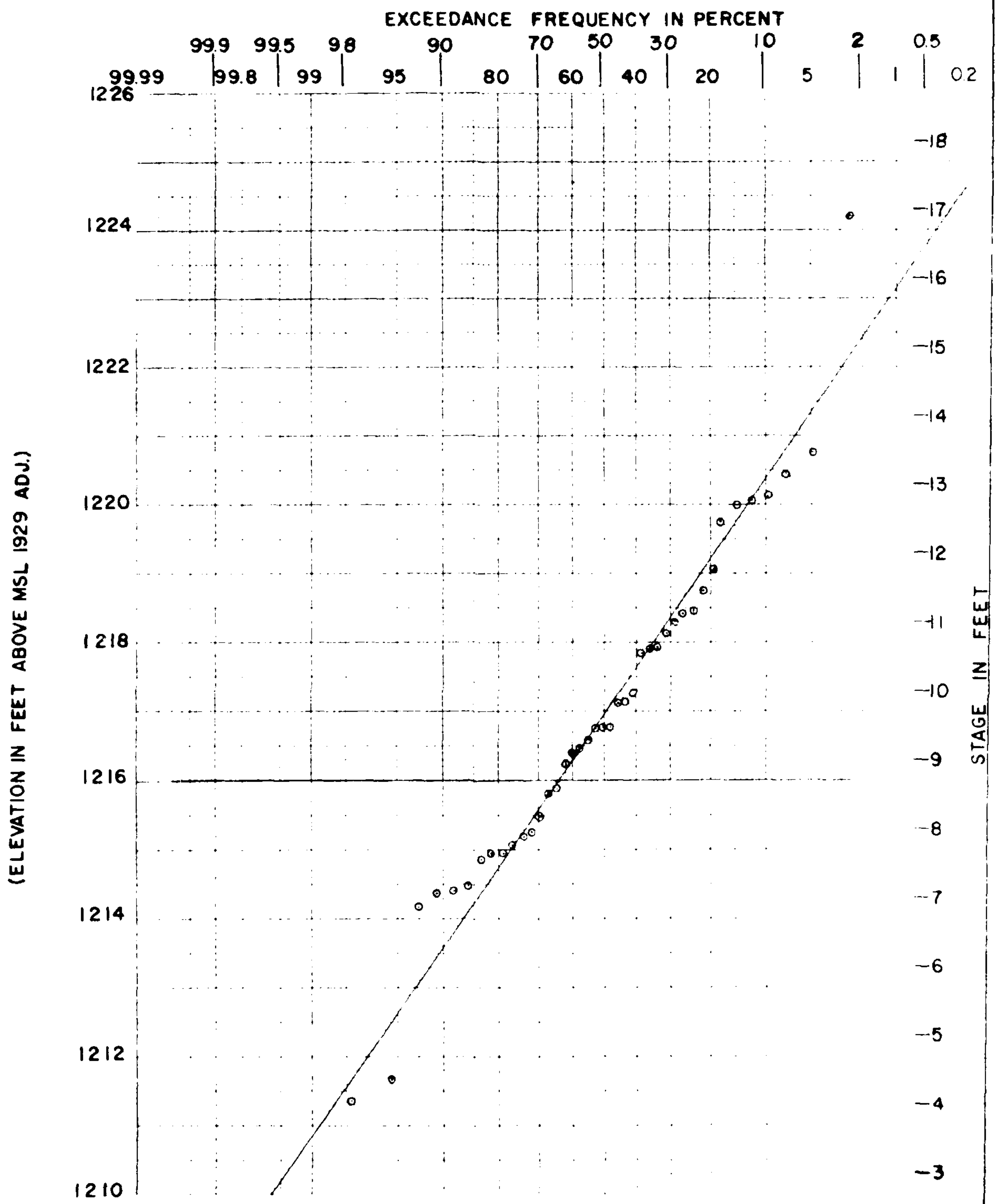
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE – FREQUENCY ANALYSIS

SANDY LAKE
1936-1976

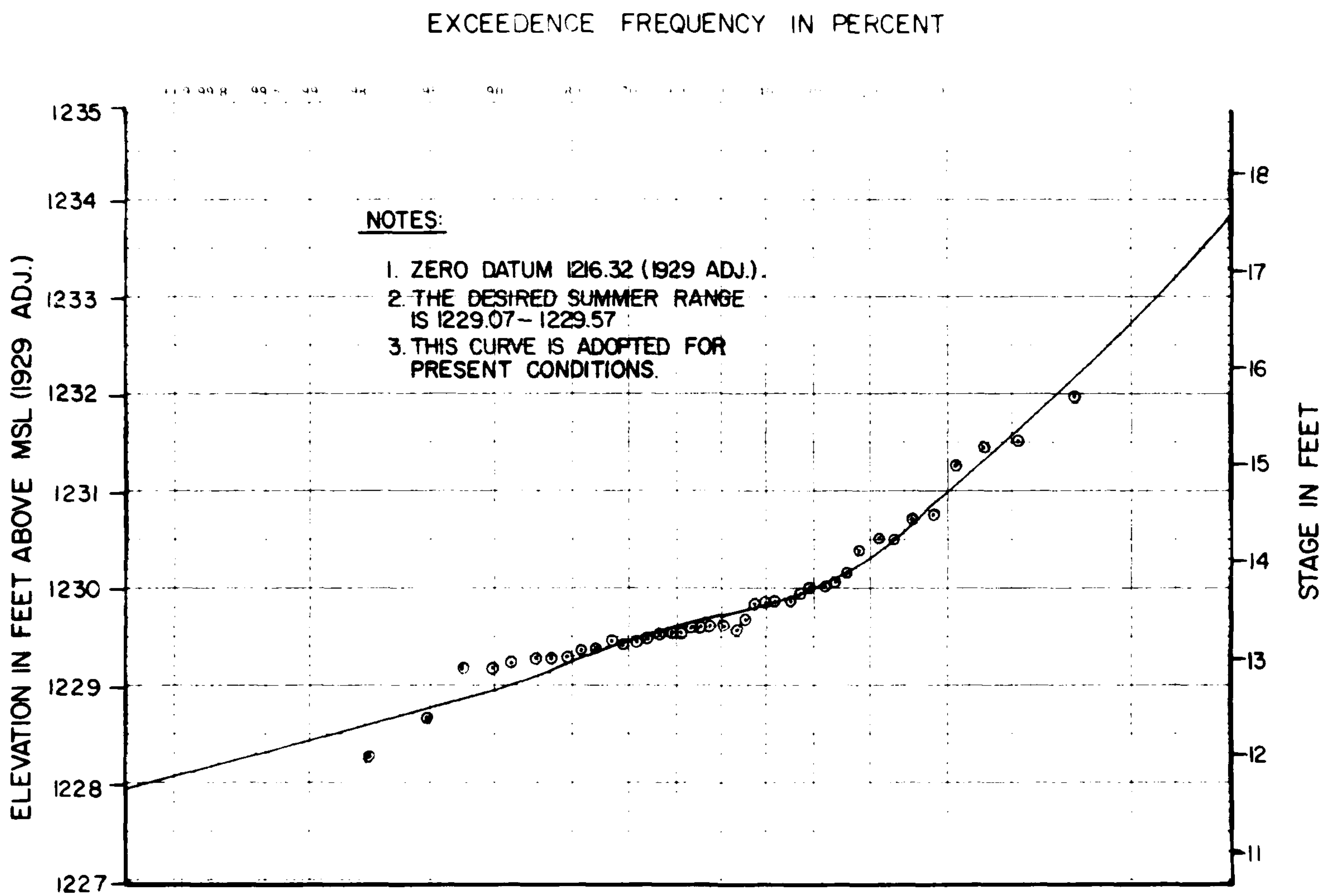
ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE FREQUENCY ANALYSIS

TAILWATER SANDY LAKE
1936-1976

ST. PAUL DISTRICT CORPS OF ENGINEERS



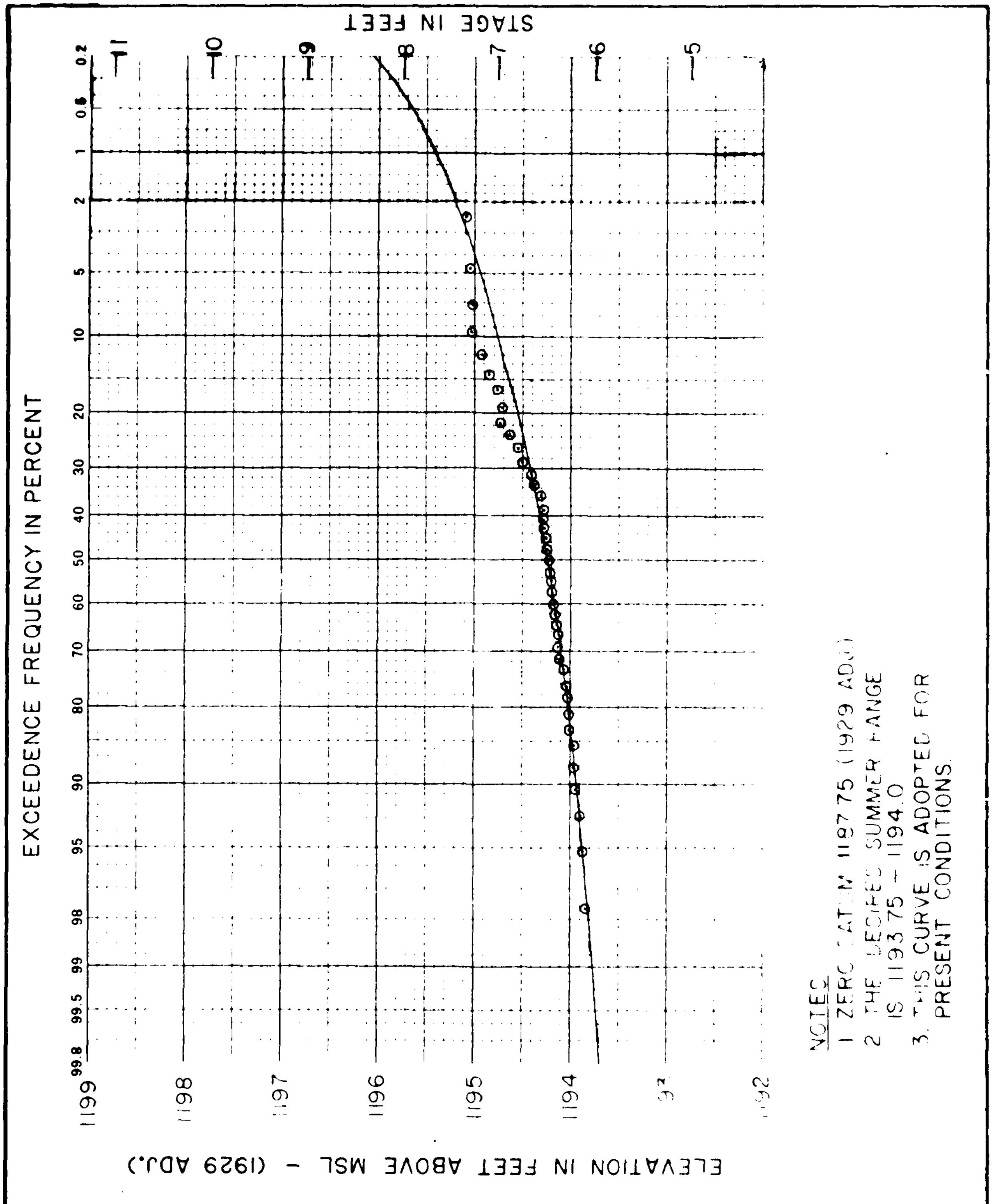
MISSISSIPPI RIVER HEADWATERS STUDY

STAGE-FREQUENCY ANALYSIS

PINE LAKE

1936-1976

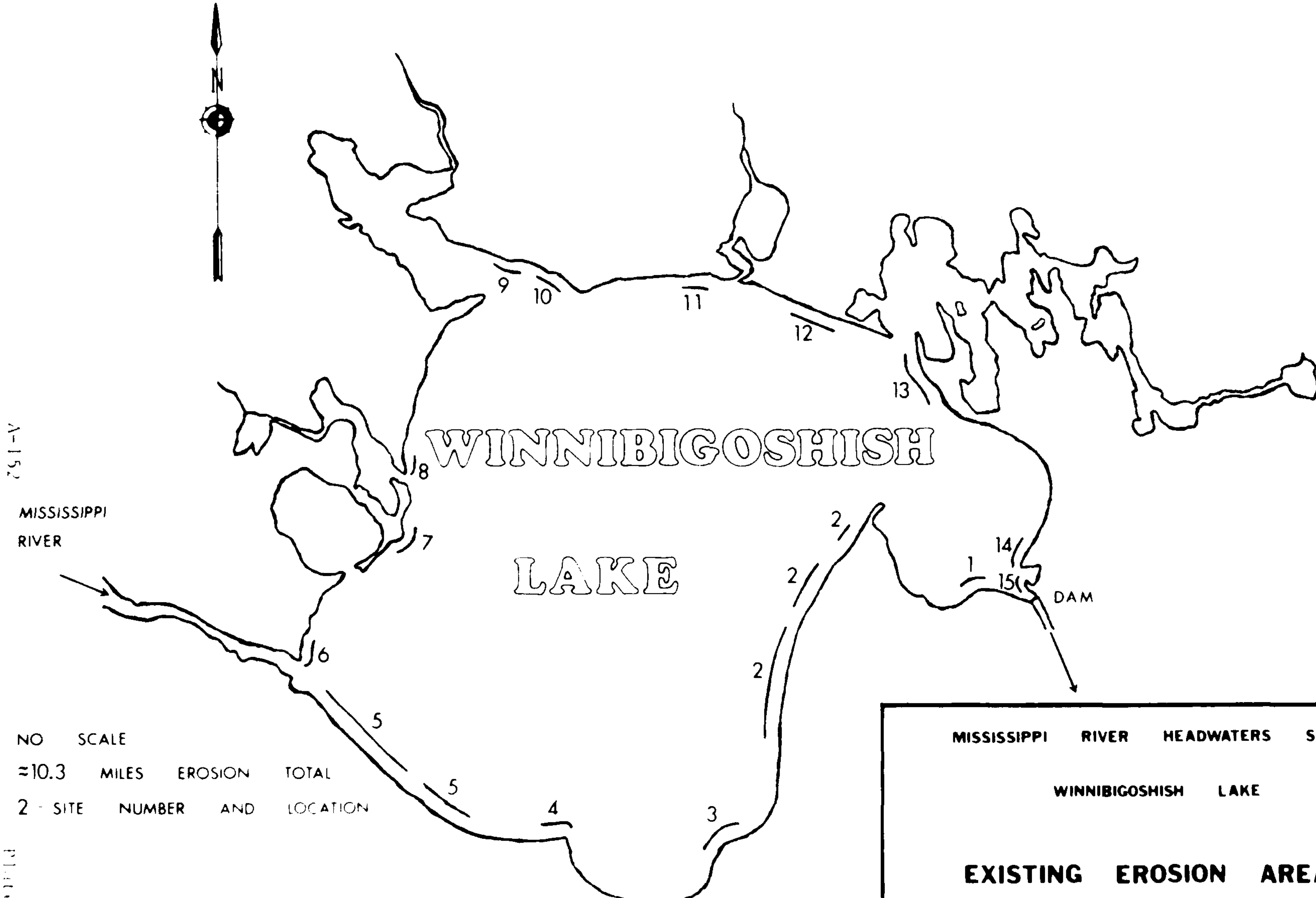
ST PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
STAGE - FREQUENCY ANALYSIS

GULL LAKE
1936 - 1976

ST. PAUL DISTRICT CORPS OF ENGINEERS



NO SCALE

≈10.3 MILES EROSION TOTAL

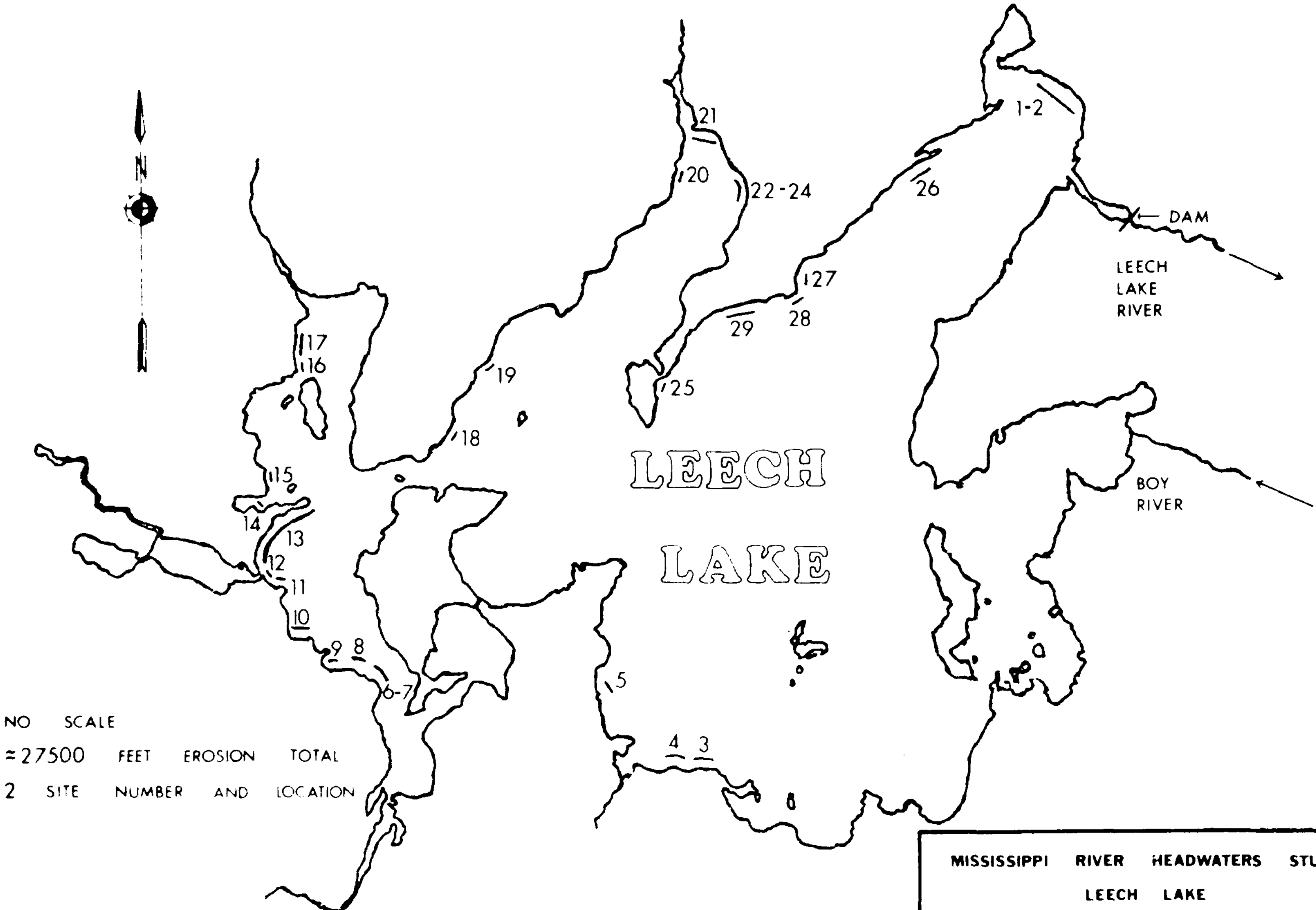
2 - SITE NUMBER AND LOCATION

MISSISSIPPI RIVER HEADWATERS STUDY

WINNIBIGOSHISH LAKE

EXISTING EROSION AREAS

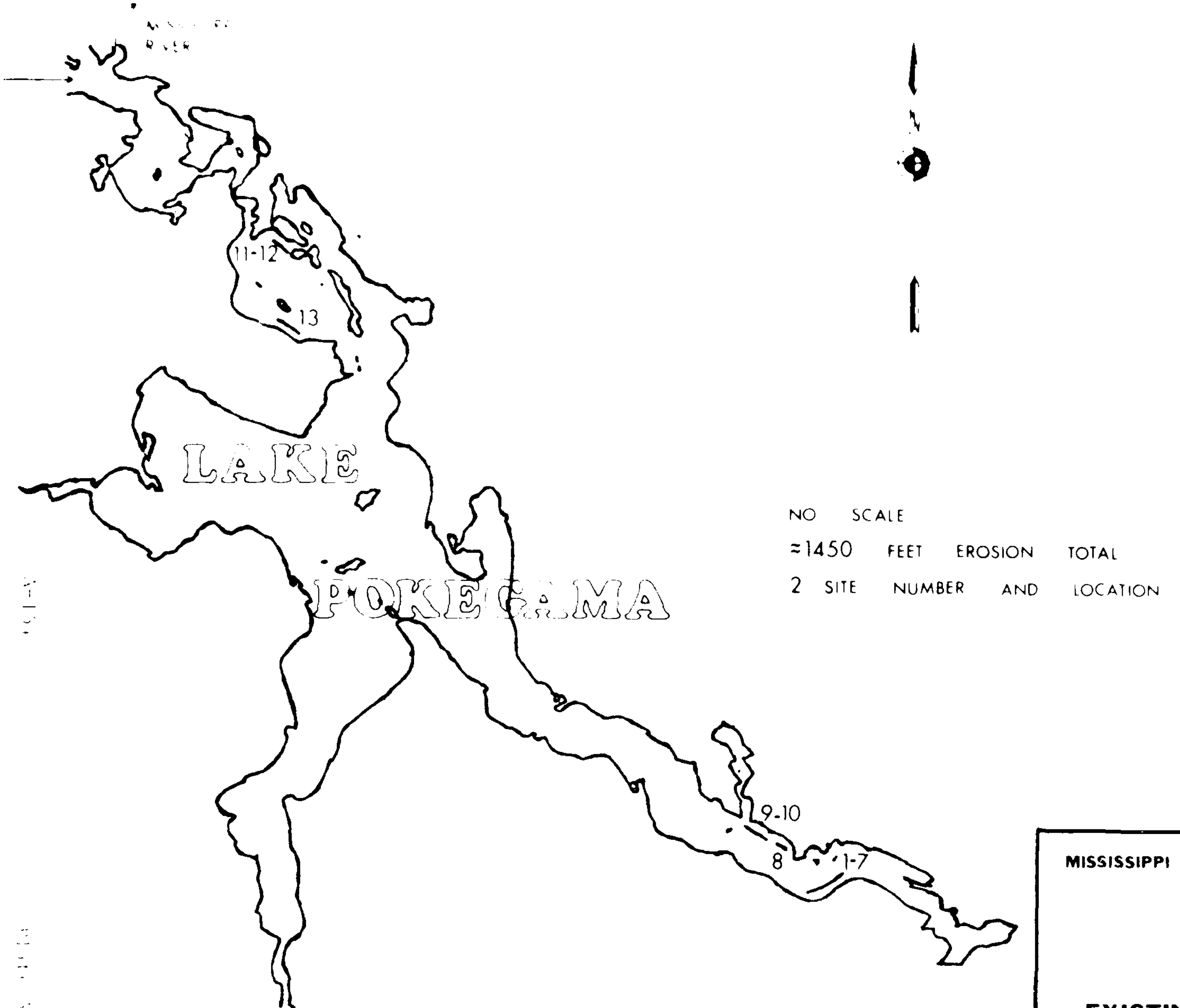
ST PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY
LEECH LAKE

EXISTING EROSION AREAS

ST PAUL DISTRICT CORPS OF ENGINEER

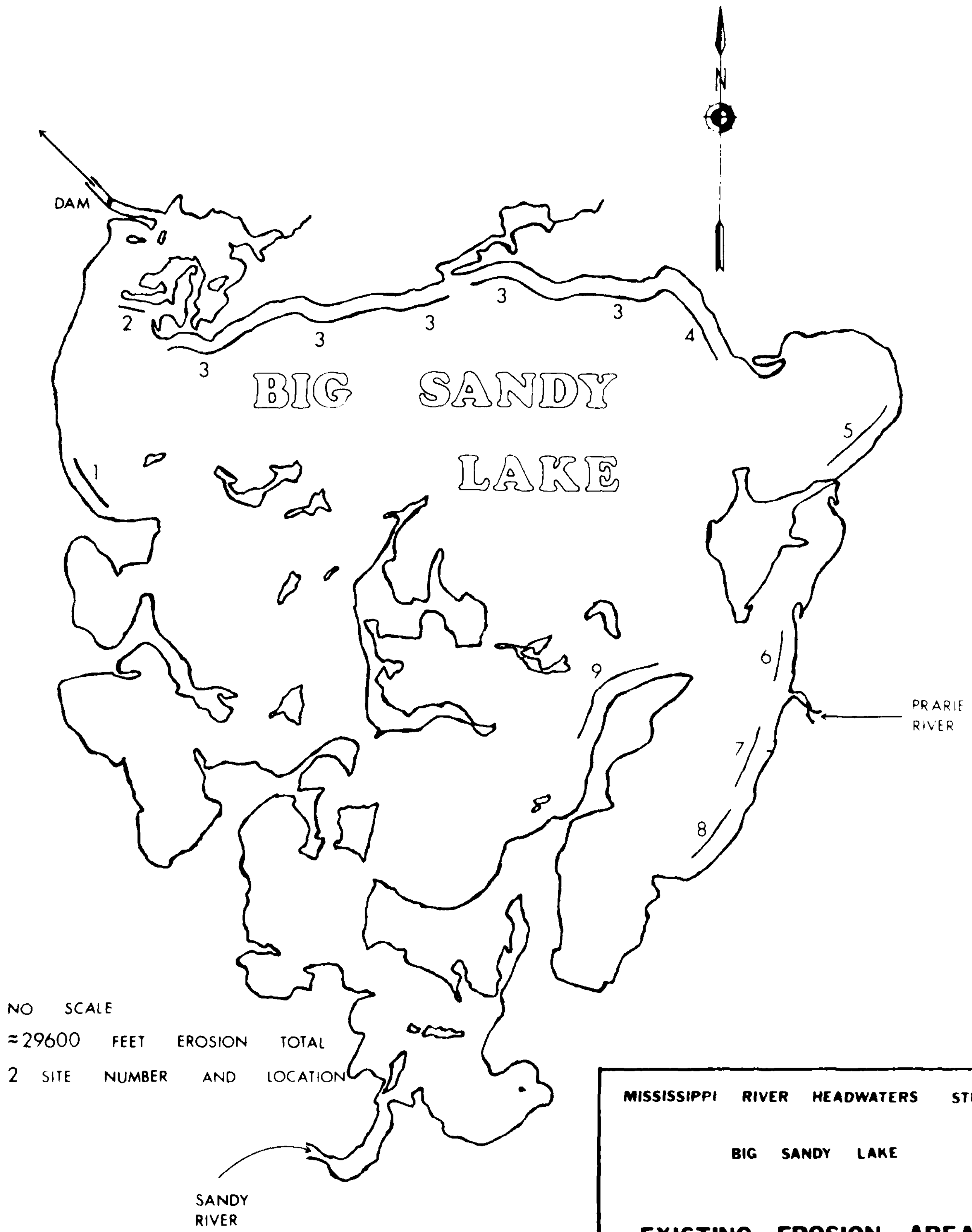


MISSISSIPPI RIVER HEADWATERS STUDY

LAKE POKEGAMA

EXISTING EROSION AREA

ST. PAUL DISTRICT CORPS OF ENGINEERS



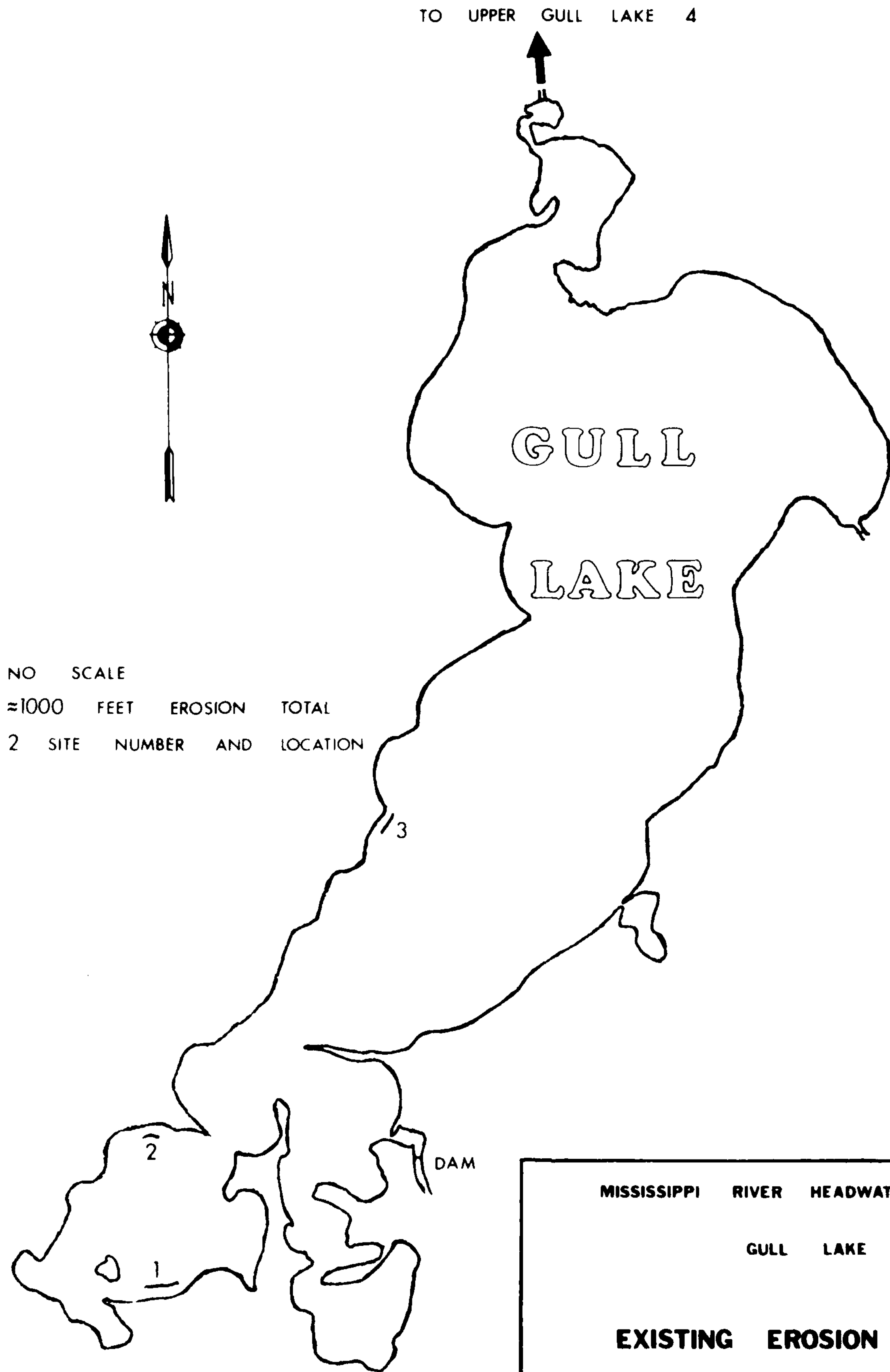
MISSISSIPPI RIVER HEADWATERS STUDY

BIG SANDY LAKE

EXISTING EROSION AREAS

ST. PAUL DISTRICT CORPS OF ENGINEERS

Plate A-

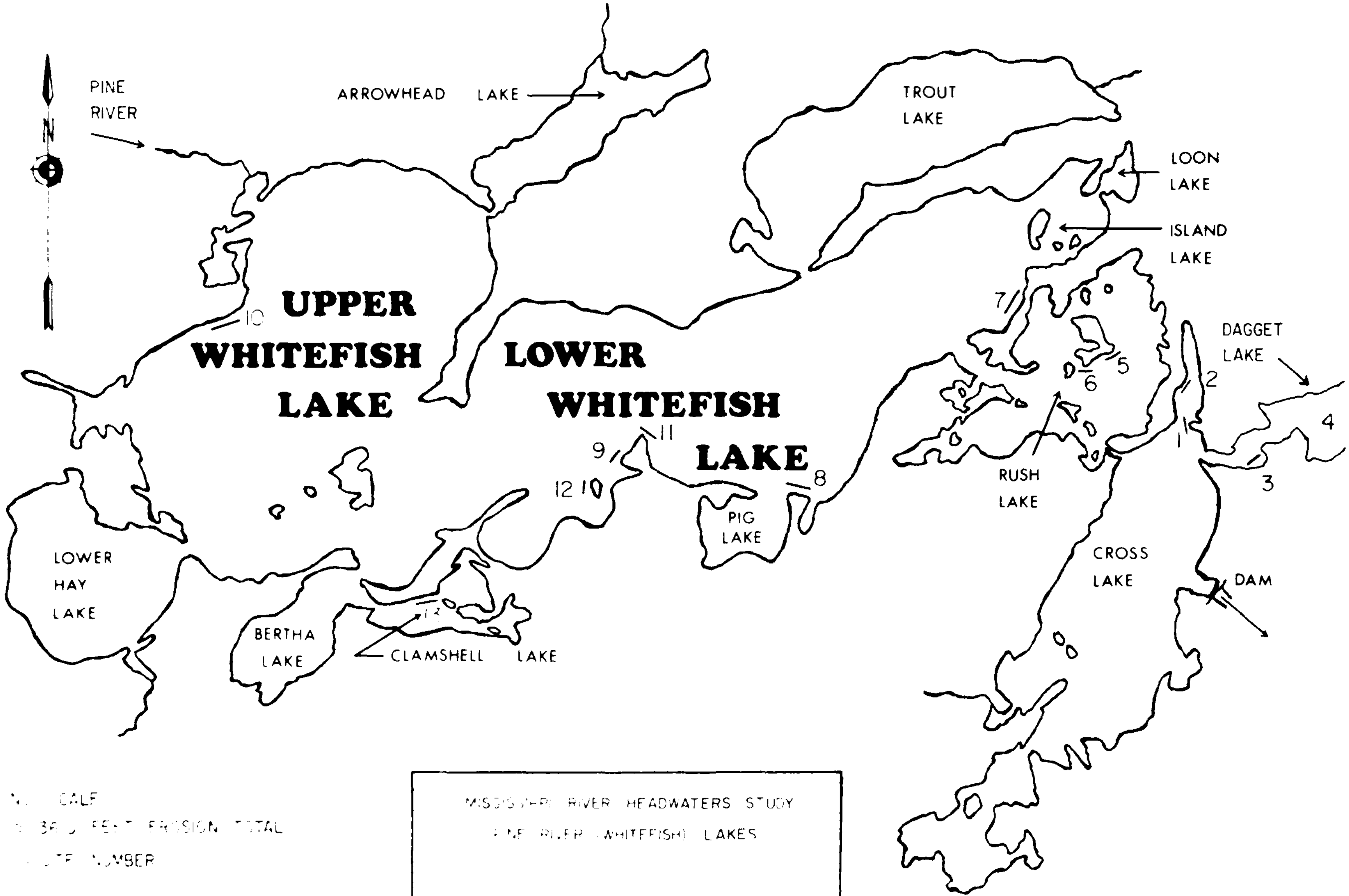


MISSISSIPPI RIVER HEADWATERS STUDY

GULL LAKE

EXISTING EROSION AREAS

ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY

PINE RIVER (WHITEFISH) LAKES

EXISTING EROSION AREAS

PROBLEM 3 - EROSION PROBLEMS DOWNSTREAM OF POKEGAMA DAM

BACKGROUND

This erosion problem was identified by a local citizen at a recreation study workshop held in the study area in September 1976. A brief review of office files and a field inspection of the affected area determined that this problem dates back to the early 1900's when flowage easements were obtained on river lands downstream from Pokegama Dam. The landowners claim that the Government acquired flowage easements in the area surrounding their property but not for the area in question.

The affected area is about 10 miles downstream from Pokegama Dam near the town of Blackberry. The problem involves several loops of the Mississippi River which have experienced channel location changes. According to the landowners, the problem took on damaging proportions in 1962 when the first of three threatened oxbows was cut off by a newly formed channel. The cutoffs effectively destroyed the use of the lands for pasture as the Mississippi River channel is too deep for cattle to wade. At present, one 40- and one 2-acre loop have been cut off and another 40-acre loop is threatened. The District has maintained that the channel changes are not the result of the headwaters lakes operations.

GEOLOGY AND SOILS

No formal subsurface investigations were conducted for the study of this problem. A general classification for soils found in this area would probably be coarse to fine textured forest soils and organic soils of glacial lake plains. The soils are similar to those found along the Mississippi River approximately 100 miles downstream and just upstream of Aitkin. There the entire area consists primarily of sandy clays overlain by 1 to 2 feet of organic clays.

HYDROLOGY AND HYDRAULIC STUDIES

Problems identified by an affected landowner include (1) shoreline erosion, (2) meandering of the Mississippi River causing channel changes and loss of usable land for pasture, and (3) lack of flowage easements on the landowner's property. The analysis was directed toward assessing the possible effects of Pokegama Dam on problems (1) and (2). Problem (3) is primarily a legal question; research has confirmed that no flowage easements were ever obtained by the Federal Government on the affected landowner's property.

Several aerial photographs and survey maps were used in an analysis of the problem development. A detailed 1898-1900 Mississippi River Commission Map (No. 244), a 1939 aerial photograph, a 1966 U.S. Geological Survey 7.5-mile quadrangle map, and a 1976 aerial photograph all show the affected area in detail. A composite overlay plate was developed using the 1898-1900 map and the 1976 aerial photograph to show the land changes during these years. These changes are shown on plate A-67.

The 1898-1900 base map details shown on plate A-67 indicate that the Mississippi River changed course a number of times before 1900. This is reflected in the number of oxbow remnants and general twisting value of the Mississippi River in this area. The 1939 aerial photograph shows a progressive cutting away of the two oxbows that were eventually cut off from the main shoreline by the time of the 1966 U.S. Geological Survey map. The two oxbows that were cut off are shown on plate A-67 and total approximately 40 acres of land.

The possible effect of Pokegama Lake operation on causing or adding to the erosion changes experienced in the Blackberry area was further evaluated. The first approach was to look at regulated versus natural Pokegama Lake outflows. The second approach was to look at what effect perimeter dikes around Pokegama Lake may have had on forcing higher flows through the Blackberry channel area. The third approach was to look at the possible increased affinity of Mississippi River water to pick up and transport suspended sediment.

First Approach

Plates A-68 through A-71 show the natural and regulated outflow from Pokegama Dam during several recent high years of record in 1962, 1966, 1969, and 1975. Although Pokegama Dam's regulated outflow in 1962 was slightly higher than natural outflow in 1962, it was considerably below the natural outflow in 1966, 1969, and 1975. Little advance warning was available for the late summer flood in 1962, compared with 1969 when the spring flood was anticipated, requiring advance flow releases from Pokegama Dam. The differences between natural and regulated flows for Pokegama Dam for a particular flood year generally relate to the size of the flood, the warning time available before an impending flood, and the ability of the upstream lakes (Winnibigoshish and Leech Lakes) to store excess flows. Plates A-68, A-69, and A-71 indicate that Pokegama Dam is not a factor contributing to the erosion and loss of oxbows experienced in the area.

Second Approach

Plate A-72 shows the location of the Blackberry erosion area, Pokegama Dam, and Hale Lake dikes area. The dikes were constructed on the east end of Pokegama Lake by the Federal Government in the early 1900's. The dikes prevented high water levels from overflowing into natural watercourses and bypassing Pokegama Dam. The dikes forced the drainage that would have bypassed the Blackberry erosion area to flow through Pokegama Dam and the Blackberry area.

Evaluation of available information on these dikes indicates that the water level in Pokegama Lake would have had to exceed elevation 1273.42 (9.0-foot stage) before it could have started flowing through the old natural channels that are now diked off. Pokegama Lake would have been discharging 3,400 cfs or more at Grand Rapids at that

elevation of overflow. The Mississippi River lowlands would already be flooded from this flow and would be further inundated by runoff from the Prairie River which has a 530-square mile drainage area (compared to a Mississippi River drainage area of 3,265 square miles above Pokegama Dam).

Third Approach

A preliminary analysis was made of the Mississippi River water quality upstream and downstream of the Blackberry area using water quality data from several recent reports published by the Minnesota Pollution Control Agency. The water quality monitoring locations are shown on plate A-73, and a list of average and maximum suspended solids and turbidity at these river locations is shown in the following table.

Mississippi River - water quality

Location[1] (river mile)	Description	Total suspended solids[2] (mg/l) Average	Maximum	Turbidity[2] (JTU) Average	Maximum
UM-1365	Bridge on State Highway 200 one-half mile north of Lake Itasca				
UM-1292	Bridge on County State Aid Highway 8 east of Bemidji	5.05	18.0	2.35	17.0
UM-1186	Bridge on State Highway 6 southwest of Cohasset (Pokegama Dam is at approximately mile 1184)	6.5	32.0	3.11	32.0
UM-1172	County Road 441 bridge 5 miles southeast of Grand Rapids (below Pokegama Dam)	7.94	16.0	4.22	7.60
UM-1178	Mouth of Prairie River	Not available		Not available	
Blackberry area	Approximately mile 1169 to 1168	Not available		Not available	
SW-1	Bridge on State Highway 65 at Jacobson	6.9	20	3.7	7.8
UM-1137	Bridge on State Highway 200 at Jacobson, approximately one-half mile downstream from Swan River mouth	12.0	58.0	7.0	30.0

(1) UM = Upper Mississippi.
SW = Swan River.

(2) Values listed are averages from a variable number of reports for 1 year.

SOURCE: The Water Quality Management Plan - Volume II, 1975, Minnesota Pollution Control Agency.

The water quality of the Mississippi River and tributaries in the Grand Rapids to Jacobson reach generally ranges from good to excellent according to the Minnesota Pollution Control Agency's 1975 and 1976 Water Quality reports. The suspended solids and turbidity values shown in the previous table are compared with the following effluent standards for point discharges established by the Minnesota Pollution Control Agency.

Effluent standards for point discharges

Parameter	Limitations (1)		
	Water pollution control regulations		
	Chapters 14 and 15	Chapter 28	Chapter 29
Total suspended solids (mg/l)	(2)	30	30
Turbidity (JTU)	25	25	25

(1) Effluent limitations for discharges are specified in the State water pollution control regulations - chapter 14, intrastate waters; chapter 15, interstate waters; chapter 28, the Mississippi River above Grand Rapids; and chapter 29, the Mississippi River from Grand Rapids to the mouth of the Rum River.

(2) Standards must be at least as stringent as 30 mg/l and no more stringent than 5 mg/l.

A definition of "suspended solids" and "turbidity" and their application to an erosion process are described in the following paragraphs.

Suspended Solids (total nonfilterable residue). - In natural waters, suspended solids consist of erosion silt, organic detritus, and plankton. Man's activities, however, alter and augment the suspended solids in surface water by discharge of liquid wastes from communities and industries, gravel washings, iron mine wastes, and dust blown into streams. Suspended solids are the main cause of turbidity and discoloration in water, although there often is not a direct correlation.

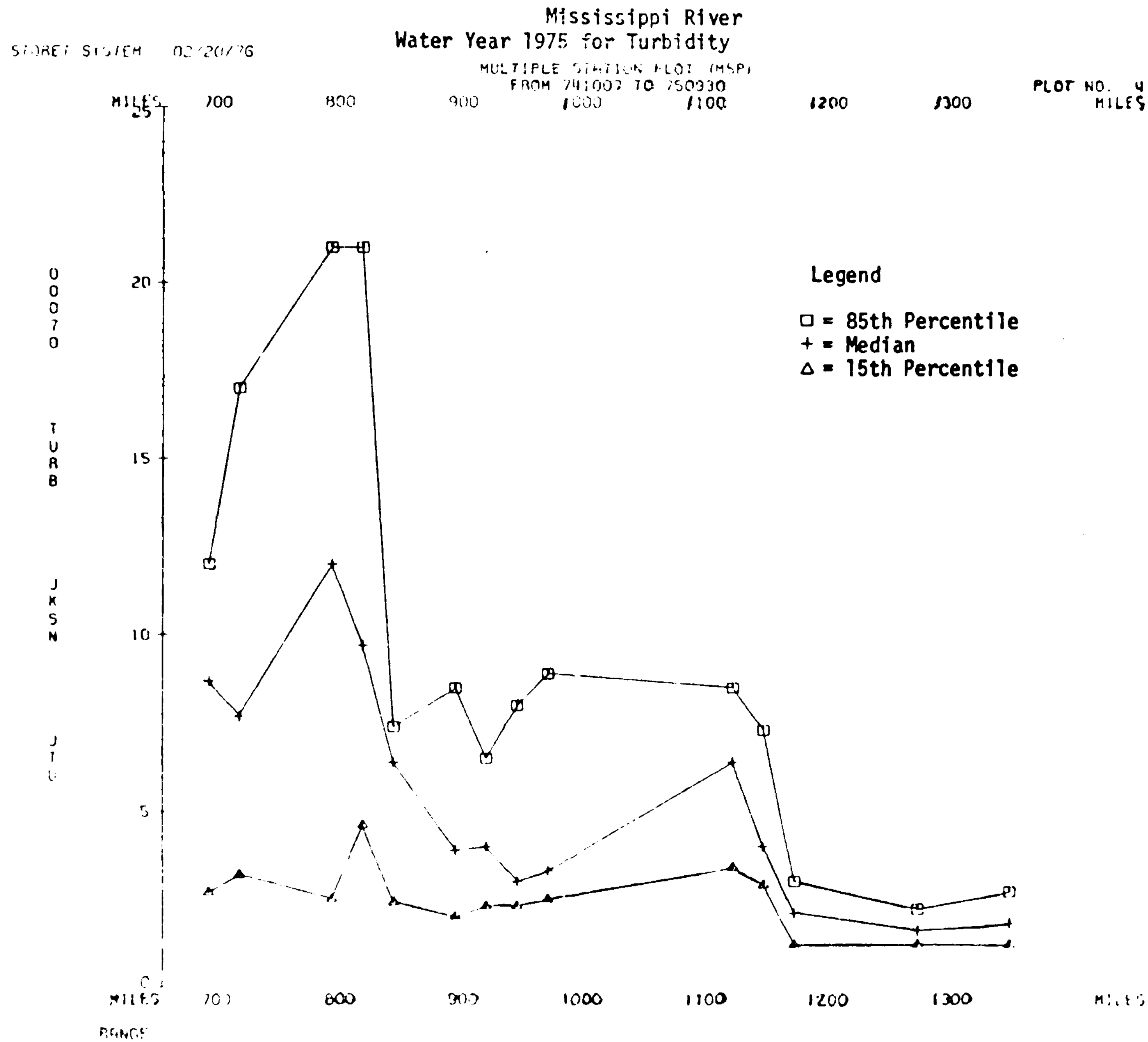
The discoloration is aesthetically offensive and in highly turbid waters restricts the penetration of sunlight, which reduces the production of oxygen by photosynthesis. In large amounts, suspended solids interfere with many industrial processes. They also affect aquatic organisms by blanketing stream or lake bottoms, spawning beds, or other desirable bottom area. Suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging gills and respiratory passages.

Turbidity. - The turbidity of water is attributable to suspended and colloidal matter, which disturbs clearness and diminishes the penetration of light. It is a measure of the extent to which the intensity of light passing through the water is reduced by the suspended colloidal matter. Turbidity may be caused by microorganisms or organic detritus; silica or other mineral substances, including zinc, iron, and manganese compounds; clay or silt; industrial and municipal wastes; and natural erosion products. High turbidity is aesthetically undesirable in drinking water supplies or water used for recreation activities. It interferes with industrial processes such as laundries, laundering, bottling beverages, brewing, production of textiles, and production of pulp and paper. At very high concentrations, it is lethal to fish life. Turbidity modifies the temperature structure of ponds and interferes with biological productivity.

Evaluation of the water quality data available at six locations on the Mississippi River from Lake Itasca to Jacobson indicates that the Mississippi River 5 miles southeast of Grand Rapids, at the County Road 441 bridge, is only 1 part per million higher in suspended solids and turbidity than the Mississippi River near State Highway 6, southwest of Cohasset (upstream of Pokegama Dam). This indicates that no unnatural sediment "pickup" occurs downstream of Pokegama Dam and in the nearby Blackberry area.

The suspended solids and turbidity are 50 and 75 percent higher, respectively, at the Jacobson location, approximately 47 miles downstream from Pokegama Dam, than at the County Road 441 bridge just upstream from the Blackberry erosion area. The increase in suspended solids and turbidity appears to result from point and nonpoint source discharges into the Mississippi River and its tributaries in the area from Grand Rapids to Jacobson and farther downstream. Typical examples of point source discharges are from those wastewater treatment plants and iron mines. Examples of nonpoint source discharges are natural erosion, runoff from agricultural lands, and other unknown sources.

The increase in turbidity for the reach of the Mississippi River within Minnesota is shown on the following computer plot taken from the Minnesota Pollution Control Agency 1976 Water Quality Inventory report, section 305(b).


STORET SYSTEM 02/20/76
Mississippi River
Water Year 1975 for Turbidity
MULTIPLE STATION PLOT (MSP)
FROM 741001 TO 750930
PLOT NO. 4
MILES
700
800
900
1000
1100
1200
1300
MILES
00070
TURB
JKSN
JTU
25
20
15
10
5
0
MILES
RANGE
Legend
□ = 85th Percentile
+ = Median
Δ = 15th Percentile

COST ESTIMATE

Cost estimates were developed for a structural plan to restore 40 acres of land previously lost for pasture in the Blackberry area and to protect another 40-acre loop that could be cut off in the future. The cost estimates and benefits for recovering lost access and for protecting threatened access are shown in the following table. Neither plan is economically feasible.

Detailed estimate of construction costs

Item	Unit	Quantity	Unit cost	Total cost: 1977 prices (6 5/8%)	Total cost: 1981 indexed prices (7 5/8%)
Restore 40 acres of pasture					
First cost					
Fill	CY	2,190	$3.00	$6,570	-
Riprap	CY	410	20.00	8,200	-
Contingencies				1,485	-
Engineering and design				1,100	-
Supervision and administration				1,100	-
Total first cost				18,455	$24,750
Annual costs					
Annualized first cost (1)				1,300	1,900
Operation and maintenance				700	1,000
Total annual costs				2,000	2,900
Total annual benefits (2)				800	1,100
Benefit-cost ratio				0.41	0.38
Protect 40 acres of wooded pasture					
First cost					
Fill	CY	2,270	3.00	6,810	-
Riprap	CY	235	20.00	4,700	-
Contingencies				1,050	-
Engineering and design				900	-
Supervision and administration				900	-
Total first cost				14,360	19,250
Annual costs					
Annualized first cost				1,000	-
Operation and maintenance				570	-
Total annual costs				1,570	2,290
Total annual benefits (2)				800	1,100
Benefit-cost ratio				0.51	0.48

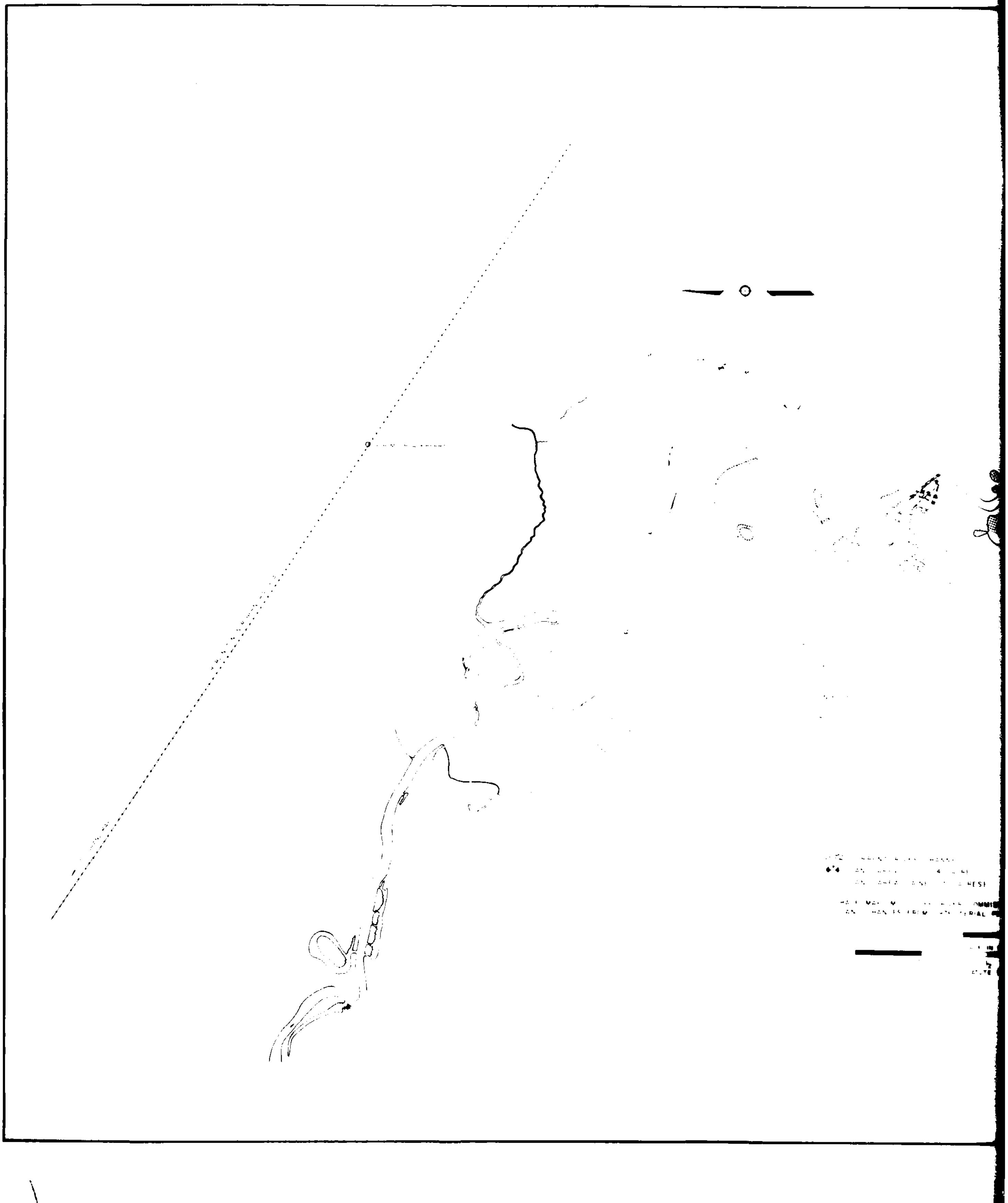
(1) 50-year project life.
(2) Preliminary annual benefits were derived using estimated value of $20 per acre which is the current estimated value of the riverine area for pasture purposes.

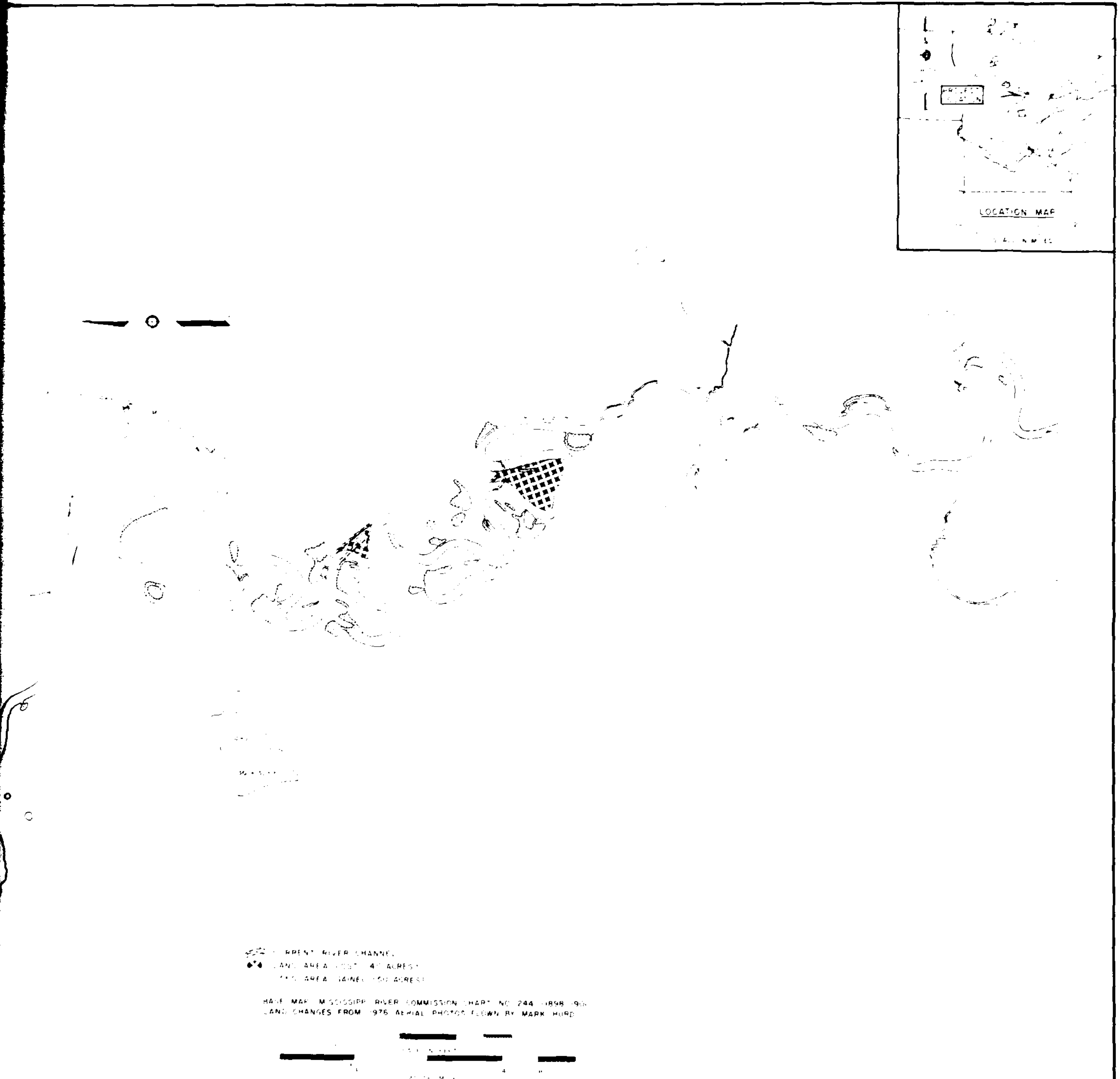
RECOMMENDED ACTION

No economically feasible solution was identified for the problem area located downstream of Pokegama Dam near Blackberry. No structural measures are recommended for this area which, over the past 20 years, has experienced several channel changes determined to be part of natural river processes. No additional study of this problem is recommended.

PLATE SUMMARY

Number	Item
A-[illegible]	Blackberry Area erosion.
A-[illegible]	Flood hydrograph 1962.
A-[illegible]	Flood hydrograph 1966.
A-[illegible]	Flood hydrograph 1969.
A-[illegible]	Flood hydrograph 1975.
A-[illegible]	General location map.
A-[illegible]	Water quality monitoring network.





MISSISSIPPI RIVER HEADWATERS STUDY

BLACKBERRY AREA EROSION

ST. PAUL DISTRICT
CORPS OF ENGINEERS

PLATE A-74

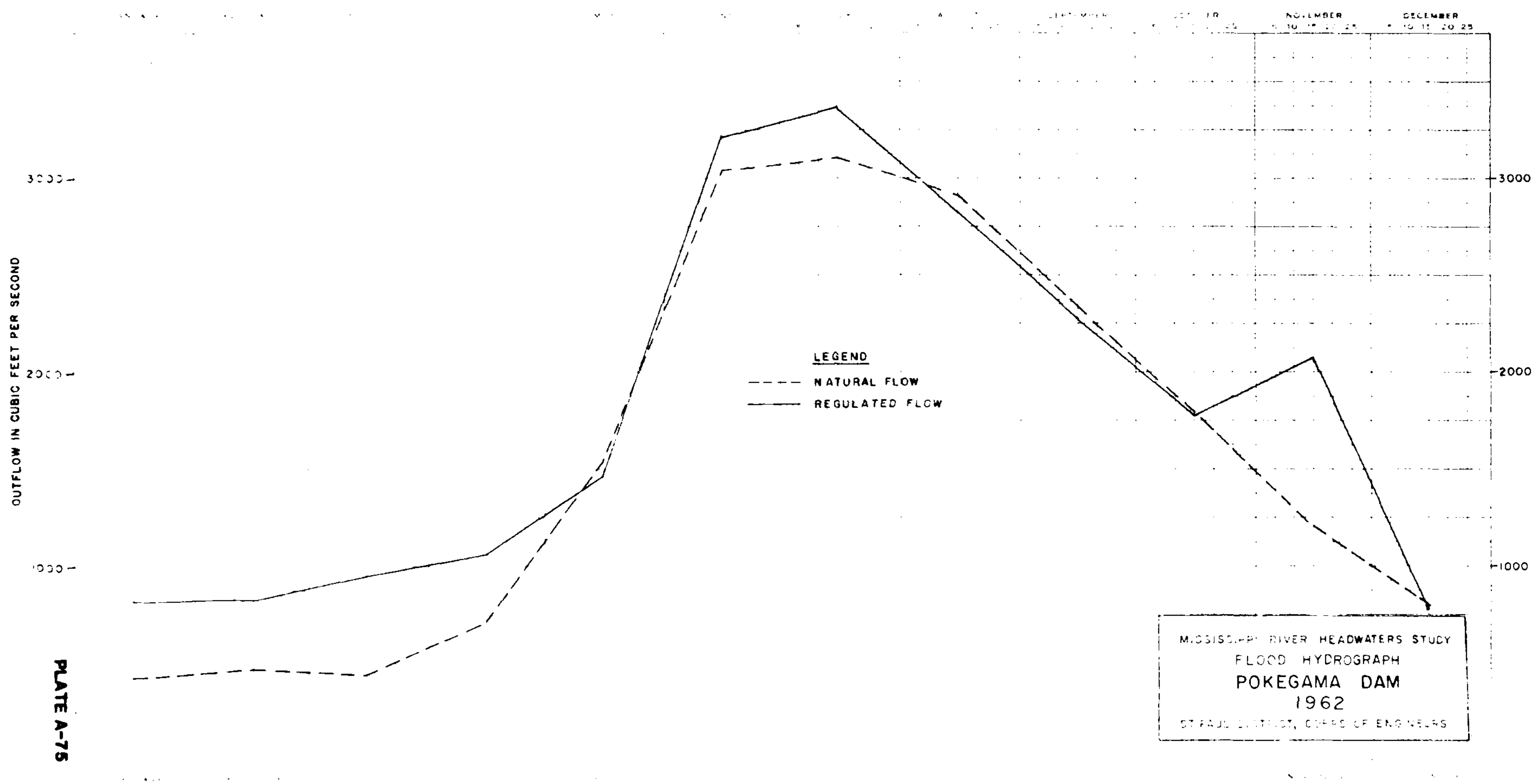

NOVEMBER
DECEMBER
10 15 20 25
3000
2000
1000
OUTFLOW IN CUBIC FEET PER SECOND
LEGEND
NATURAL FLOW
REGULATED FLOW
MISSISSIPPI RIVER HEADWATERS STUDY
FLOOD HYDROGRAPH
POKEGAMA DAM
1962
ST PAUL DISTRICT, CORPS OF ENGINEERS

PLATE A-75

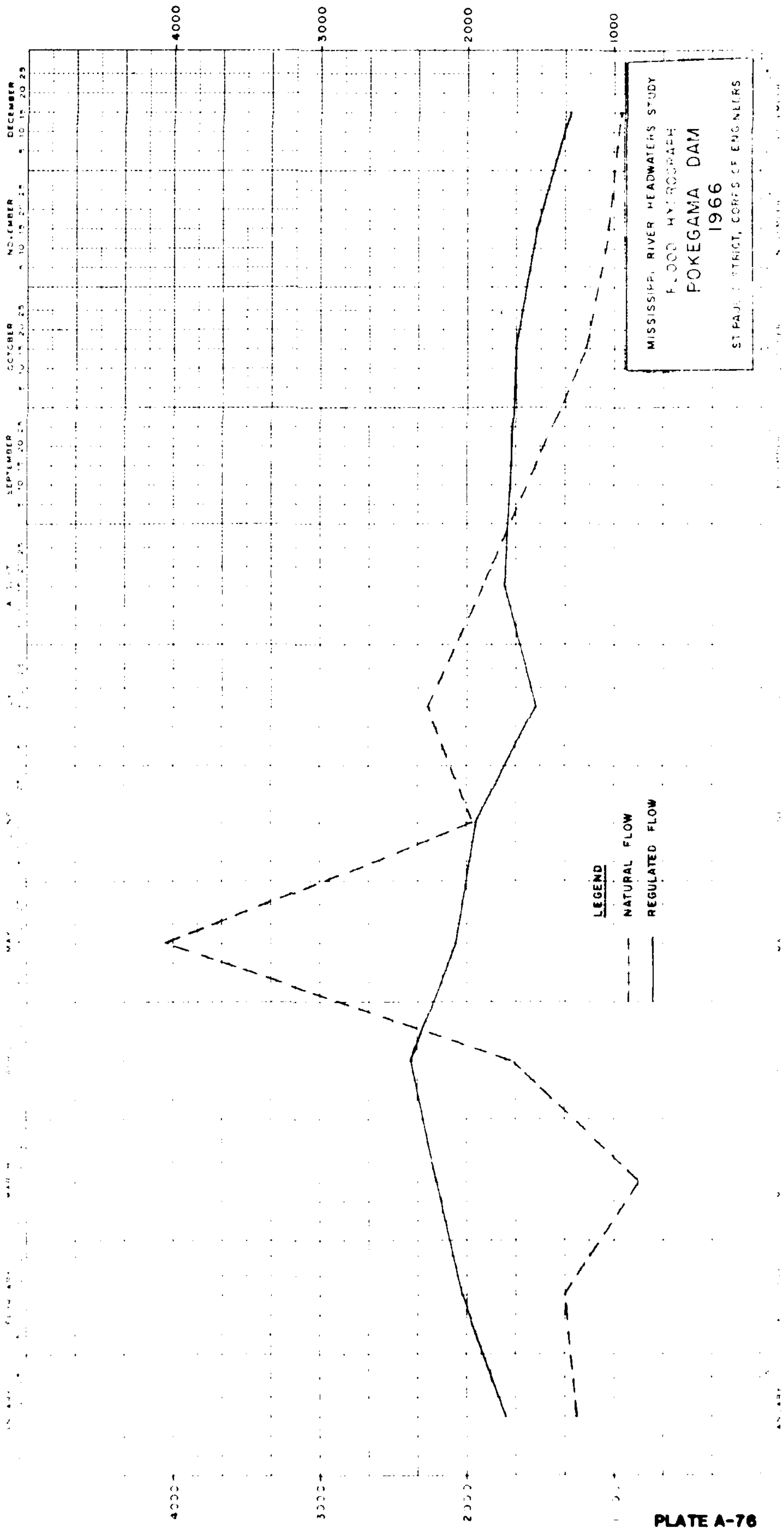

MISSISSIPPI RIVER HEADWATERS STUDY
FLOOD HYDROGRAPH
POKEGAMA DAM
1966
ST PAUL DISTRICT, CORPS OF ENGINEERS
LEGEND
NATURAL FLOW
REGULATED FLOW
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
4000
3000
2000
1000

PLATE A-76

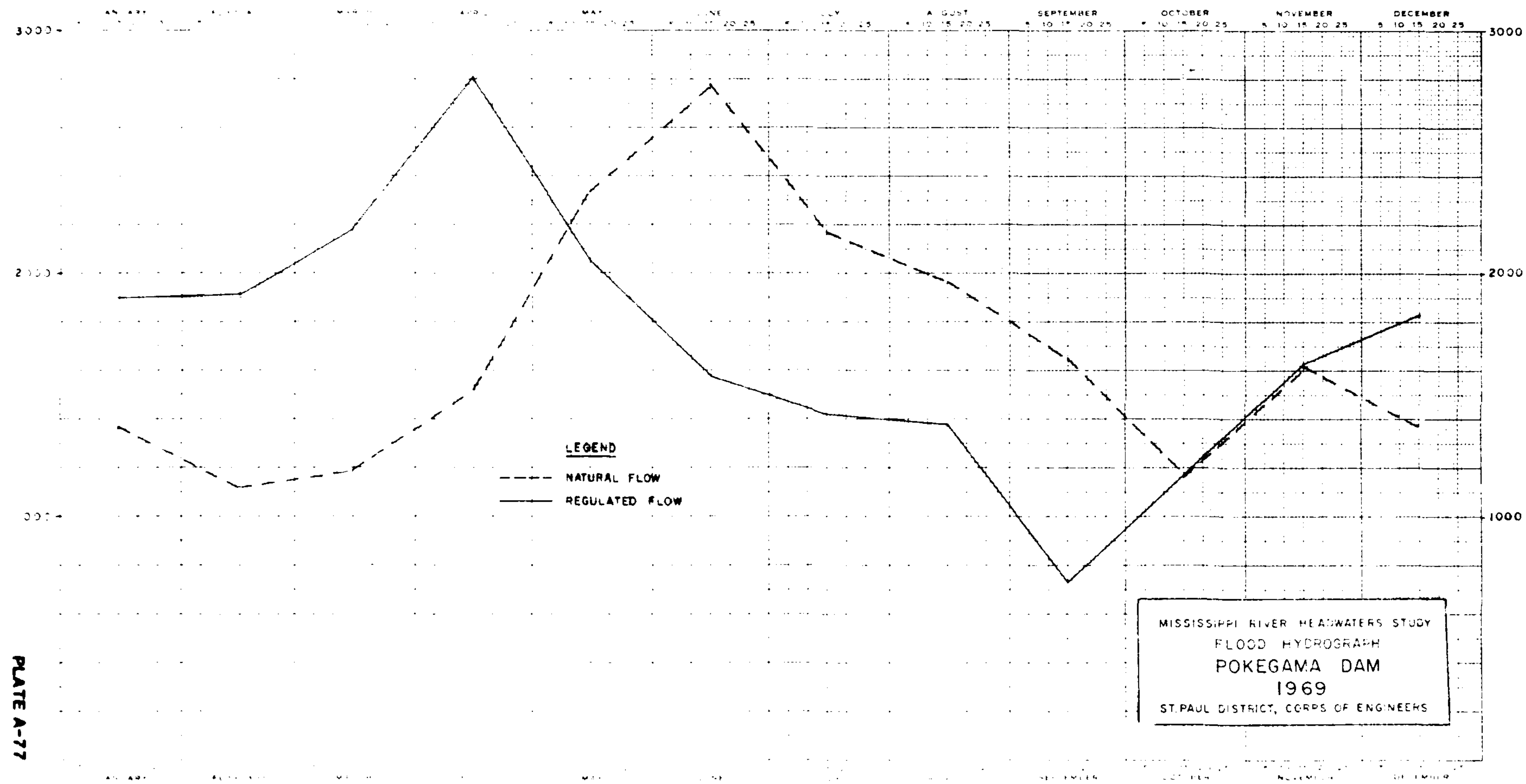

MISSISSIPPI RIVER HEADWATERS STUDY
FLOOD HYDROGRAPH
POKEGAMA DAM
1969
ST. PAUL DISTRICT, CORPS OF ENGINEERS
LEGEND
NATURAL FLOW
REGULATED FLOW
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
3000
2000
1000

PLATE A-77

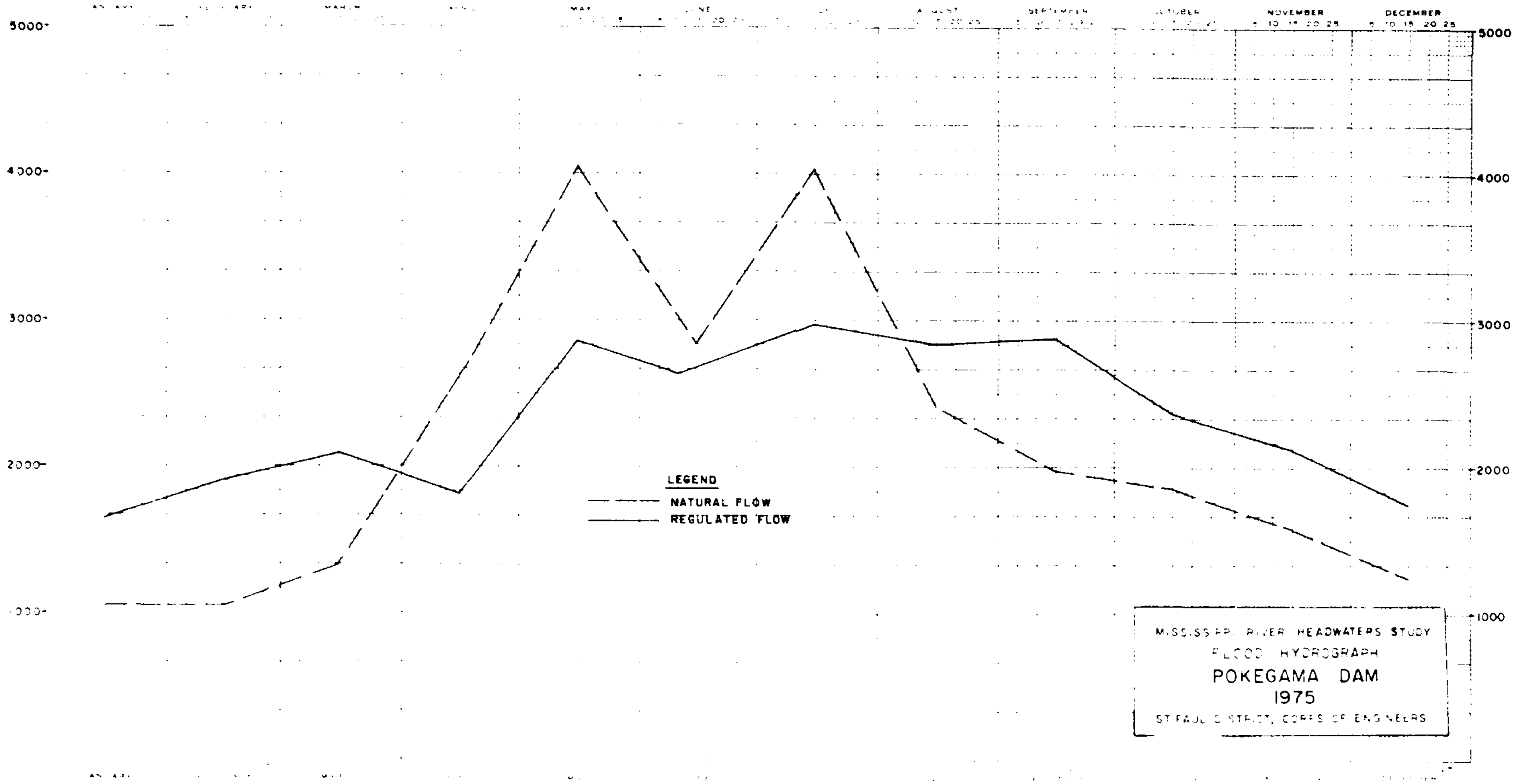
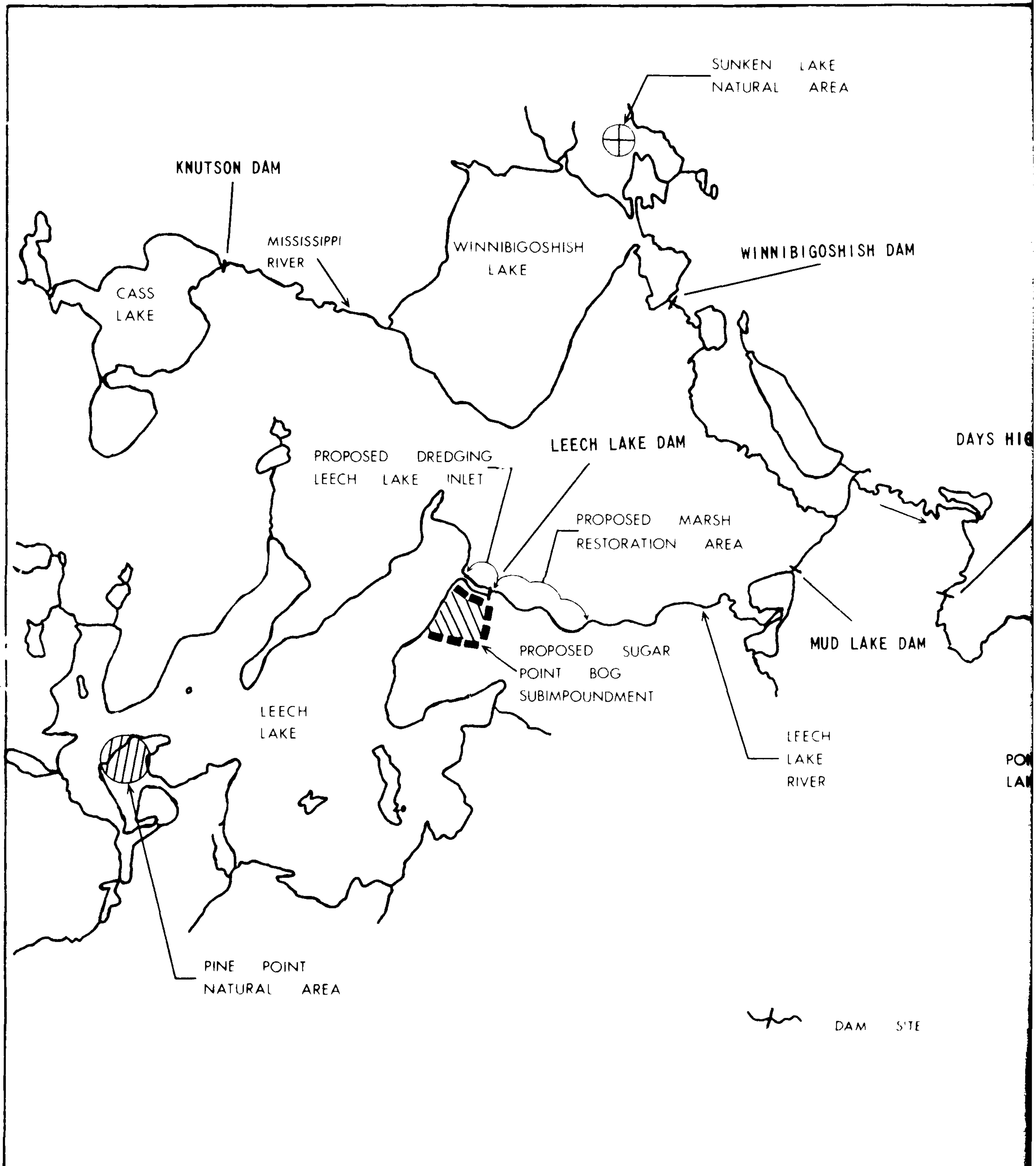
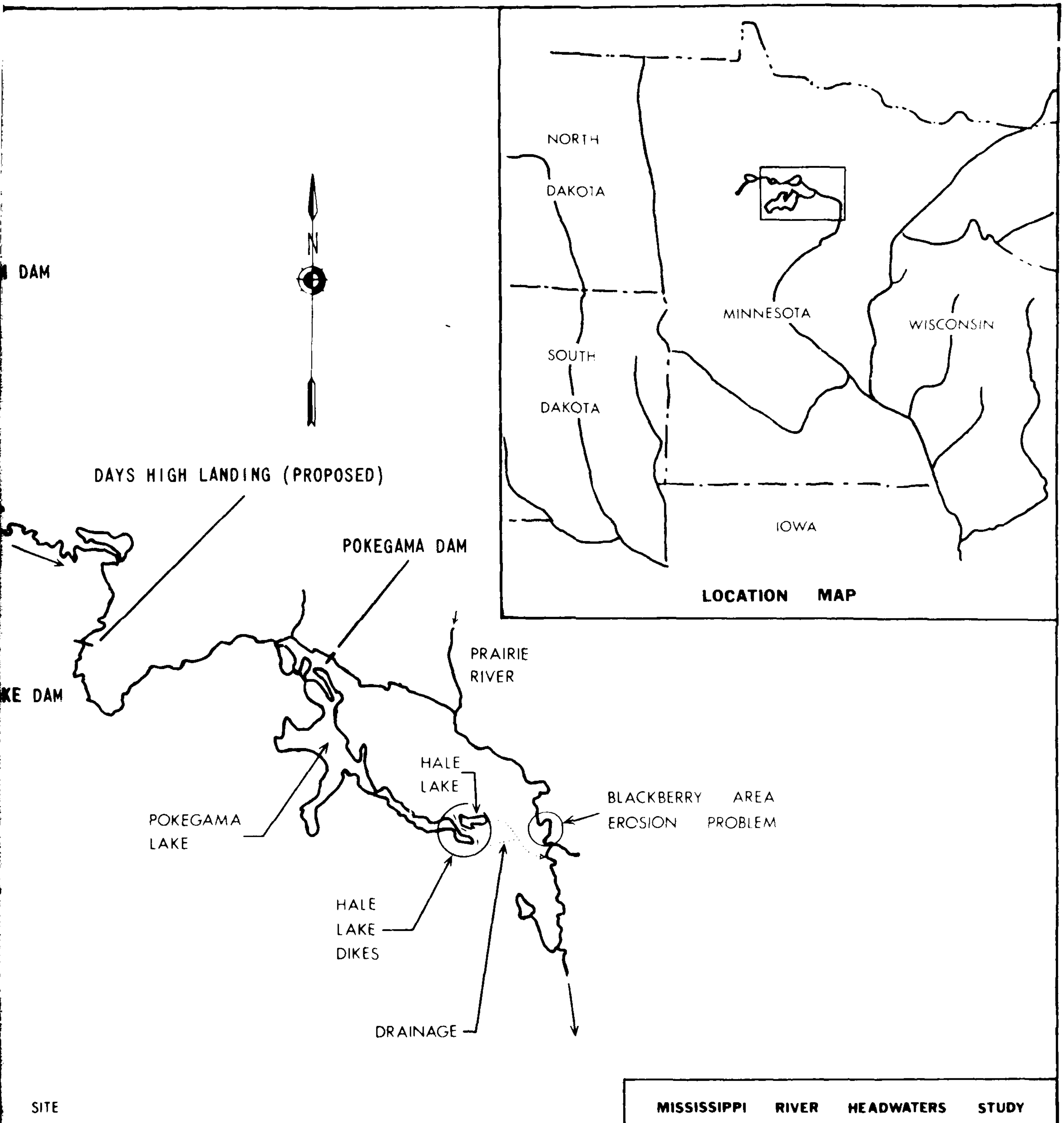

MISSISSIPPI RIVER HEADWATERS STUDY
FLOOD HYDROGRAPH
POKEGAMA DAM
1975
ST PAUL DISTRICT, CORPS OF ENGINEERS
LEGEND
NATURAL FLOW
REGULATED FLOW
OUTFLOW IN CUBIC FEET PER SECOND
5000
4000
3000
2000
1000
MAY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

PLATE A-78


SUNKEN LAKE
NATURAL AREA
KNUTSON DAM
MISSISSIPPI
RIVER
WINNIBIGOSHISH
LAKE
WINNIBIGOSHISH DAM
CASS
LAKE
PROPOSED DREDGING
LEECH LAKE INLET
LEECH LAKE DAM
DAYS HI
PROPOSED MARSH
RESTORATION AREA
MUD LAKE DAM
PROPOSED SUGAR
POINT BOG
SUBIMPOUNDMENT
LEECH
LAKE
LEECH
LAKE
RIVER
PINE POINT
NATURAL AREA
DAM SITE



MISSISSIPPI RIVER HEADWATERS STUDY

GENERAL MAP

ST. PAUL DISTRICT CORPS OF ENGINEERS

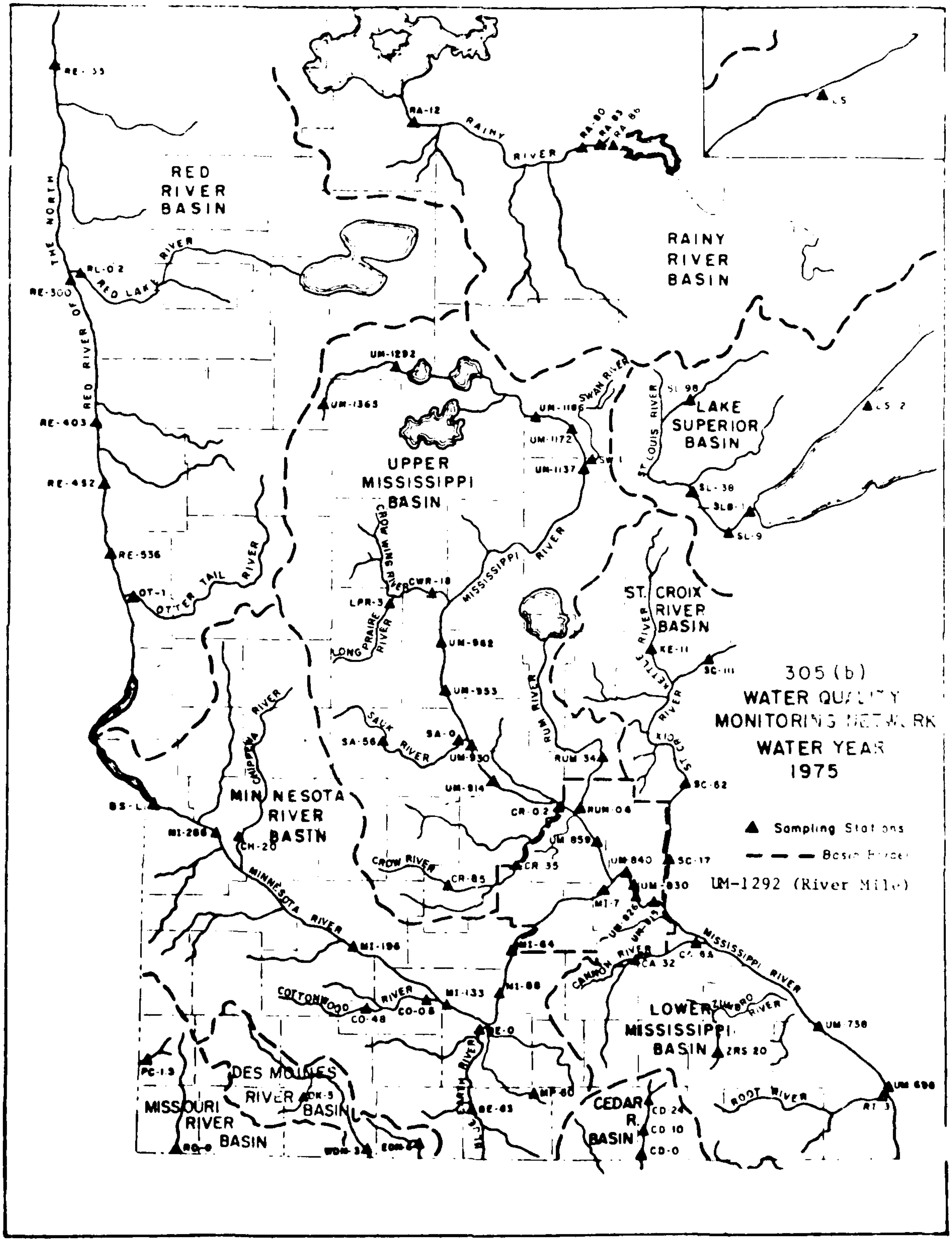

RED RIVER BASIN
RAINY RIVER BASIN
LAKE SUPERIOR BASIN
UPPER MISSISSIPPI BASIN
ST. CROIX RIVER BASIN
MINNESOTA RIVER BASIN
LOWER MISSISSIPPI BASIN
CEDAR R. BASIN
MISSOURI RIVER BASIN
305 (b)
WATER YEAR
1975
UM-1292 (River Mile)
RAINY RIVER
MISSISSIPPI RIVER
MINNESOTA RIVER
OTTER TAIL RIVER
CROW RIVER
SAUK RIVER
RUM RIVER
ROOT RIVER
CANNON RIVER
COTTONWOOD RIVER
LONG PRAIRE RIVER
CROW WING RIVER
ST. LOUIS RIVER
SWAN RIVER
RED LAKE RIVER

Plate A-80

PROBLEM 4 - WHITE OAK LAKE WATER LEVELS

BACKGROUND

At public meetings in the 1960's, local interests in the headwaters lakes area indicated that low and fluctuating water levels in the White Oak Lake area had detrimental effects on wild rice, fish, and wildlife.

In the late 1960's and early 1970's, the St. Paul District studied the feasibility of constructing a dam at Days High Landing (mile 1203.8 above the mouth of the Ohio River). The dam would control water levels in the White Oak Lake area, downstream from the confluence of the Leech Lake and Mississippi Rivers, and upstream from Pokegama Lake. An interim feasibility report dated 21 March 1972 found the project economically feasible and recommended that the United States undertake construction of the dam.

The State of Minnesota did not support the project, however, claiming insufficient data, primarily detailed topography, prevented an accurate appraisal of project benefits. The report was returned to the St. Paul District in 1975 for further consideration with the State of Minnesota. No further study was accomplished on the proposed Days High Landing Dam due to lack of funding. Plate A-74 shows the location of the proposed Days High Landing impoundment and related facilities. All elevations for the Days High Landing structure referred to in this report are the same as those in the 21 March 1972 interim feasibility report, and are in U.S. Engineer Datum rather than 1929 adjustment. The 1929 adjustment mean sea levels would be 0.85 foot lower than those expressed in U.S. Engineer Datum.

GEOLOGY AND SOILS

Description

The proposed Days High Landing damsite is located in the Western Lake section of the Central Lowlands physiographic province. Locally, the Mississippi River occupies a shallow valley with a broad, marshy floodplain. The approximately 600-foot-wide floodplain at the site is one of the narrowest reaches of the valley. The river flows south in a channel 90 feet wide at the site. The channel is bounded on the northwest by a low, marshy floodplain. Southeast of the channel, the ground surface is slightly higher and covered with a thick growth of trees and brush. The ground surface under the proposed embankment varies from a low elevation of 1264.0 in the river channel to 1283.0 away from the river. The soil at the proposed damsite consists of a thin deposit of recent alluvium underlain by glacial drift which regionally exceeds 100 feet in thickness. Precambrian metamorphic and igneous rocks capped by thin Cretaceous sediments underlie the glacial drift at a depth below the influence of the proposed structures.

The geology of the Days High Landing area is influenced by both glacial and alluvial deposition. Recent alluvium mantles the surface at the site and is primarily silty fine sand with a maximum known thickness of 11.2 feet. Deposits of peat occur with the alluvium in low marshy areas at and upstream from the damsite. The glacial deposits underlie the alluvium and are well over 100 feet thick. The investigated portion of these deposits consists of a dense, silty, clayey, and gravelly sand till between approximate elevations 1270 and 1245. The till is underlain by a sand bed of undetermined thickness. Two water bearing zones are present at the site. The upper zone is restricted to the alluvium where the water level is close to the ground surface. The lower zone is the sand underlying the till. Water in the lower zone is confined under artesian pressure by the overlying impervious till. In January 1965 the piezometric surface of the artesian water was between elevations 1285.0 and 1290.6. Bedrock is deeply buried under the glacial deposits and is well below the influence of the proposed structures.

Alluvium

The alluvium consists primarily of medium dense, silty fine sand with deposits of peak in the marshy area northwest of the river channel. The maximum thickness of alluvium encountered in the borings taken was 11.2 feet. The alluvium is characterized by a high groundwater surface which coincides with the ground surface in the marshy areas.

Glacial Deposits

The glacial deposits were identified by Dr. George M. Schwartz, Consulting Geologist, in a detailed 1965 report on the geology of the site. The glacial deposits are well consolidated in that they were covered after deposition by two later glaciations and, thus, are subjected to considerable compaction. Two glacial units were identified at the site. The upper unit is a very dense till which consists of clayey, silty, gravelly sand. The unit is impervious and has a low natural moisture content. The till acts as an impervious barrier that prevents downward percolation of water from the overlying alluvium. The till extends to approximately elevation 1245.0 where it is underlain by a sand bed of undetermined thickness. The sand is dense and was apparently derived from glacial till by sorting action. Water in the sand is confined under artesian pressure by the overlying impervious till. In January 1965 the piezometric surface of the artesian water was between elevations 1285.0 and 1290.6.

Design Considerations

The proposed control structure would be founded in the dense glacial till. The till is considered to have adequate strength to support the structure due to its high degree of consolidation. Placing the structure on piling was considered inadvisable since penetration

of the till with piling could destroy the effectiveness of the till layer as a confining bed for the artesian water in the underlying sand. Additional investigation in the area of the control structure would be necessary to determine the thickness of the artesian aquifer and the best method of lowering the piezometric surface of the artesian water during construction of the control structure. Dewatering of the alluvium would be necessary during construction of the control structure. The maximum effort needed to accomplish the dewatering would be a well-point system set to the top of the glacial till.

Subsurface Investigations

Subsurface investigations consisted of five machine borings taken in January 1965. The borings varied in depth from 15 to 40 feet, and none of the borings penetrated bedrock. The location of the drill holes is shown on plate A-75 and individual drill logs are shown on plate A-76. A check of existing water wells in the immediate area revealed that none extend into bedrock. One of the deeper wells located 6 miles north of the site at Deer River ended in glacial drift at a depth of 140 feet. Two other shallow borings were taken in a nearby low area but are not shown since field surveys taken later revealed that this area would not be flooded.

Laboratory Investigation

Laboratory tests, except for one sieve analysis, were conducted on selected boring samples at the North Central Division Soils Laboratory, Corps of Engineers, Chicago, Illinois. All samples received a minimum of laboratory visual classification. In addition, many selected samples received tests such as Atterberg limits, sieve analysis, and moisture content determination. One "Q" triaxial test and one consolidation test were performed on an undisturbed sample from boring 65-2M taken below the bottom elevation of the proposed structure.

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82

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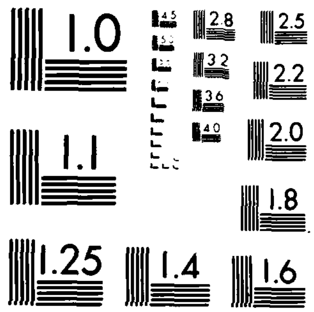


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Analysis of the borings reveals that an upper layer of alluvial material of varying thickness overlies a dense glacial till. This layer consists primarily of a silty sand (SM) containing 15 to 40 percent material passing the No. 200 sieve. A layer of peat (Pt) up to 12 feet thick was encountered in boring 65-3M. This deposit of peat and marsh mud occurs on the right bank of the existing river channel and extends back from the bank for 75 to 400 feet. A layer of clay having the borderline classification of CL-CH was encountered 6 feet below the ground surface in boring 65-5M, about 400 feet southeast of the left bank of the river. This boring should be fairly representative of foundation conditions on the left bank of the river. The glacial till underlying the alluvial blanket and overlying the artesian sand aquifer varies in depth from 10 to 25 feet. This layer consists of a dense mixture of sandy clays, silty or clayey sands, and gravels. In most cases, the sands or gravels have the borderline classification of SC-SM or GC-GM.

Three borings (65-1M through 65-3M) tapped a sand layer which produced an artesian head of from 40 to 45 feet. The net head above ground surface varied from 6.2 to 13.1 feet. The probable sources of this water pressure are the morainic areas to the northeast and southwest where the ground elevation rises about 400 feet above that at the site. Springs are common along and near the river in the surrounding area but, in view of the impervious nature of the till, it is believed that the springs are fed by water seeping through lenses of pervious material near the ground surface and not from the sand aquifer in the till. The thickness of the sand aquifer was not established by the borings because of the high heads developed.

Dewatering

The major construction problem anticipated at the proposed site would be dewatering the foundation soils for placement of the control structure and that portion of the embankment fill below the water table.

Based on available information, groundwater conditions at the site would require two separate dewatering stages. The first stage would be dewatering of the upper layer of silty sand and peat to permit placement of the foundation concrete and the earth portions of the dam in the dry. Concurrently, a second stage would be needed to reduce and control the pressure heads generated in the sand aquifer underlying the glacial till. Preliminary calculations show that some relief of artesian pressure would be required to prevent heaving during excavation for the control structure. When the concrete structure was in place, the dead load of the structure would compensate for the uplift. Both dewatering problems could be effectively solved. Further study would permit detailed design of the dewatering measures.

Earth Dam

A rolled-fill earth dam with top elevation at 1283.0 is proposed across the river channel and floodplain. The dam would tie into the proposed control structure and extend 900 feet southeast to high ground. The embankment fill would consist of compacted impervious material having a top width of 11 feet and side slopes of 1 on 3. The upstream slope would be protected with 12 inches of riprap overlying 6 inches of filter for 400 feet from the control structure. The top and balance of the slopes would be protected by sod established by seed and 6 inches of topsoil. Mandatory disposal fill to elevation 1276.0 would be required downstream and upstream from the embankment fill in the area of the river channel. Plan and sections of the embankment are shown on plates A-75 and A-76.

A layer of swamp muck and peat with an average thickness of 10 feet would be removed from within the embankment and control structure limits. All organic material removed would be replaced with compacted impervious fill. This area and the area of the control structure foundation would be dewatered by a combination of well points, sumps, and earth cofferdams.

Part of the embankment fill adjacent to the structure would be placed concurrently with the concrete within the first-stage cofferdam and with the water flowing in the existing channel. Then, a second-stage cofferdam would be constructed around the old channel bottom with the river flowing through the completed control structure. This would allow completion of the peat excavation and placement of the embankment fill in the dry. The top 12 inches under the remainder of the embankment would be stripped to remove all growth and organic materials.

Control Structure and Channels

The proposed control structure and channels would be located in the floodplain about 400 feet northwest of the river channel. The structure would be constructed of reinforced concrete founded on a spread footing located in the glacial till about 16 feet above the artesian zone. A shallow approach channel approximately 1,200 feet long and 164 feet wide would be excavated from the upstream river channel to the control structure. Downstream from the structure a 1,000-foot-long channel with a 164-foot bottom width would convey the water back to the river. No slope protection is proposed on the 1 on 3 side slopes because of the low velocities of the river. A typical section, bottom profile, and plan of the channels are shown on plate A-75. A majority of the channel excavation is expected to be peat and soft organic materials. These materials would be used as disposal fill for the existing river channel. All suitable material from the channel excavation would be used in the embankment or access road fill.

Stability and Settlement

The stability and settlement of the proposed structures were not checked for this report. The results of the "Q" test, $\phi = 19^{\circ}-30'$ and $c = 1,200$ psf (pounds per square foot), and the high blow counts recorded on the boring logs indicate that the foundations soils have ample strength for the proposed loading. The results of the consolidation test indicate

that the soil is underconsolidated. These results are in contrast to the geologic history of the area and the existing high dry density of 130.4 pcf (pounds per cubic foot). Apparently, the high percentage of sand in the sample has affected the shape of the e-log, p-curve. Additional investigations and testing would be required before making further predictions of stability and settlement.

Construction Material

Some suitable fill material for the embankment fill would be obtained from the proposed channel excavation. The balance of the material needed would be obtained from a borrow area. Adequate borrow may be obtained within one-half mile of the proposed damsite. Filter gravel, riprap, and concrete aggregate may be obtained from commercial plants at Duluth or St. Cloud. Detroit Lakes has a commercial plant which is an approved source of concrete aggregate. Riprap may also be obtained from a quarry located between Cohasset and Grand Rapids or from the Pittsburg Pacific Company of Crosby.

HYDROLOGY AND HYDRAULIC STUDIES

The operation of the headwaters lakes has been revised at various times since the construction of the dams. Only since 1943 have the lakes been operated under the present Corps of Engineers plan of operation. Therefore, the available records of discharge and stage represent various regulated conditions. To obtain uniform results, the records were modified to reflect conditions that would have occurred under the present Corps of Engineers plan of operation. At Days High Landing, only limited discharge records for the years 1945-50 are available. Therefore, the high discharge-frequency curve is based on computed annual mean daily discharges for the years 1930-61 that reflect the present Corps of Engineers plan of operation. The annual

stage hydrographs at Willow Beach, White Oak Point, and Days High Landing are available for the years 1943-61. The high and low stage-frequency curves developed for Willow Beach, White Oak Point, and Days High Landing are for June and July according to current operating procedures.

High Discharge-Frequency Curve

The high discharge-frequency curve at Days High Landing was developed for the years 1930-61 and adjusted to 77 years of records, 1885-1961. The curve is plotted graphically from Beard's table of plotting positions as published in "Statistical Methods in Hydrology" by Leo R. Beard, January 1962. The flows at Days High Landing are computed mean daily flows that reflect the present Corps of Engineers plan of operation. The curve shows that the design flood of 4,000 cfs has a 45-year frequency and that a discharge of 6,000 cfs would be a very rare flood. The high discharge-frequency curve for conditions at Days High Landing is included on plate A-77.

High Stage-Frequency Curves

The high stage-frequency curves for June and July at Days High Landing, White Oak Point, and Willow Beach were developed for the years 1943-61 and adjusted to 32 years of computed stage records (1930-61). The curves are plotted graphically from Beard's table of plotting positions. The stages at the three locations are peak recorded stages for current operating procedures for June and July, adjusted to longer term computed records and then adjusted to reflect the present Corps of Engineers operation plan. The three high stage-frequency curves for the Pokegama flowage are included on plate A-78. The curve at White Oak Point shows that, on an annual basis, the elevations of 1277.3, 1278.0, 1278.5, and 1279.0 would be exceeded 25, 15, 10, and 6 percent of the years, respectively. The percentages are based on conditions prevailing with all stop logs removed.

Low Stage-Frequency Curves

The low stage-frequency curves for June and July at Days High Landing, White Oak Point, and Willow Beach were developed for current operating procedures for the years 1943-61 and adjusted to 32 years of computed stage records (1930-61). The curves are plotted graphically from Beard's table of plotting positions. The stages at the three locations are low stages for June and July, obtained from the records and adjusted to computed records which reflect the present Corps of Engineers operation plan. The three low stage-frequency curves for the Pokegama flowage are included on plate A-79.

Hydrology and Hydraulics of the Dam

The drainage area above the proposed dam and below the Winnibigoshish and Leech Lake Dams is about 570 square miles. About 128 square miles of this area is in the Deer River tributary and would drain directly into the proposed pool.

The dam at Days High Landing would control water surface levels in the vicinity of White Oak and Little White Oak Lakes during low stages in the Pokegama pool. The dam would be on the main stem of the Mississippi River upstream from the bridge on Itasca County Road 18 at Days High Landing. The stop-log structure would have six bays of stop logs and one sluice gate bay with the sill of the dam at elevation 1266.0. A concrete control section would be built across a new channel on the right riverbank with a service bridge over the structure and tieback levees on the right and left banks and crossing the natural river channel. The control structure with all stop logs removed would have the capacity to pass a discharge of 3,000 cfs with a loss of head of 0.09 foot with a 6-foot stage at Pokegama Dam. With a stage increase to 12 feet at Pokegama Dam, the structure would pass 2,000 cfs with a loss of head of 0.04 foot with all the stop logs removed. For both of these discharges and stages, the water level at White Oak Point could be maintained at 1279.0, the upper reasonable elevation of the pool and the normal design condition for the dam.

As the discharges at Days High Landing increase and the stages at Pokegama Dam increase, the effect of the structure would decrease and backwater effects upstream at Willow Beach caused by the dam would approach a minimum.

A study was conducted on flow records from 1930-61 adjusted for current operating procedures to determine the ability of the structure to maintain stable water levels in the pool at elevations between 1274.0 and 1279.0. Under present Corps of Engineers operation of the headwaters lakes, an elevation of 1277.3 at White Oak Point would have been exceeded by over one-half foot during June and July in about 18 percent of the years. Elevations of 1278.0, 1278.5, and 1279.0 at White Oak Point could have been maintained during June and July without an increase of over one-half foot in 90, 94, and 96 percent of the years, respectively. The percentages are based on optimum operation of the stop logs. They indicate that for elevations 1277.3, 1278.0, 1278.5, and 1279.0 the dam would be out of control some time during June and July and the control would revert to Pokegama Dam in 18, 10, 6, and 4 percent of the years, respectively. The study of past records also indicates that during August and September the flows would be inadequate to maintain the pool at elevations 1277.3, 1278.0, 1278.5, and 1279.0 in about 3 percent of the years. Therefore, based on the operating pool level established, less than optimum conditions for wild rice production would exist in the pool between 21 and 7 percent of the years that wild rice production would be attempted.

Purpose of Operation of Proposed Days High Landing Dam

The plan of operation of the Days High Landing Dam is based on obtaining the maximum beneficial use of the lake for all concerned by stabilizing the water levels in the White Oak Lake area. Preference is given to the requirements for improvement of natural resources with

particular emphasis on producing desirable conditions for wild rice production. The present Corps of Engineers plan of operation for Pokegama, Winnibigoshish, and Leech Lakes produces fluctuations in discharge and stage in the White Oak Lake area with detrimental effects to wild rice production and fish and wildlife resources. The dam at Days High Landing would control the water surface levels in the vicinity of White Oak and Little White Oak Lakes during the periods of normal flows, low flows, and low stages at the Pokegama pool. The dam would be effective in obtaining a more stable minimum level with gradual fluctuations. Days High Landing Dam would have no flood control storage other than storage now controlled by Pokegama Dam. During high flows, the dam would be wide open and control would revert to Pokegama Dam.

Effects of Proposed Days High Landing Dam on High Flows

The pool formed by a dam at Days High Landing would have considerable slope during high flows. Operation of the proposed dam would be correlated with the discharges from Winnibigoshish and Leech Lake Dams and in conjunction with Pokegama Dam and Lake. During high flows, all stop logs in the proposed dam would be removed, if necessary, to prevent stages from exceeding elevation 1279.0 at White Oak Point. With all of the stop logs removed, the control of the pool would revert to Pokegama Dam. The pool level above the proposed dam would then depend on the discharge through the pool and the stage and discharge at Pokegama Dam. As the stage at White Oak Point receded to 1278.5, the stop logs in Days High Landing Dam would be replaced to maintain the pool at approximately 1278.5 and control of the proposed pool would revert back to Days High Landing Dam. During all other nonflood and low-flow periods, control of the pool would remain at the proposed dam. The stop logs and discharges would be adjusted to keep fluctuations gradual and incremental increases to a maximum of one-half foot.

For 1950 and 1952 which include the flood of record and the second largest flood, respectively, in the headwaters area, routings were made through the proposed pool using the current plan of operation of the headwaters lakes. The routings show that with the proposed conditions the peak stages above elevation 1278.5 at Days High Landing and White Oak Point would be unchanged from existing conditions. The peak stages in Pokegama Lake might increase or decrease slightly because of the small amount of storage in the proposed pool which would no longer be released before the initial flood rise or stored during the rise and recession of the floods. Peak discharges from Pokegama Lake remain approximately the same for preproject and project conditions. Four peaks from 1950 and 1952 for preproject and project conditions determined from the routings are listed in the following table.

Flood peaks, 1950 and 1952

Location	Date	Elevations: Present conditions	Elevations: Proposed conditions	Date	Elevations: Present conditions	Elevations: Proposed conditions
1950 flood peaks						
White Oak Point	14 May	1279.0	1279.0	25 Aug	1280.6	1280.6
Days High Landing	14 May	1278.9	1278.9	31 Aug	1278.9	1278.9
Pokegama Lake gage	20 May	1278.1	1277.9	2 Oct	1274.8	1275.3
Pokegama Dam - upper gage	18 May	1277.8	1277.7	2 Oct	1274.7	1274.9
1952 flood peaks						
White Oak Point	23 Apr	1277.3	1278.5	27 July	1279.2	1279.2
Days High Landing	23 Apr	1277.2	1278.5	27 July	1277.6	1278.5
Pokegama Lake gage	23 Apr	1276.9	1276.5	27 July	1277.4	1277.7
Pokegama Dam - upper gage	23 Apr	1276.8	1276.2	27 July	1277.2	1277.5

Control of Water Level Fluctuations

To obtain maximum beneficial use of the lake, the water level fluctuations must be reduced to a magnitude and frequency which would occur in marshes under natural conditions. The water level must be relatively stable after the spring runoff with no more than one-half foot increase in water level during the floating leaf and flowering stages for wild rice which occur in the Deer River area from 15 June to 15 July. Also, decreases in stage must be avoided during the wild rice harvest, usually about 1 September, to enable canoes and flat-bottom boats to navigate in the shallow areas. The stop-log control structure would require extensive operation from June through September to keep the fluctuations gradual and any increases or decreases in water levels to a maximum of one-half foot. During later studies, consideration would be given to a movable crest (bascule or fabric) or some other type of gated control that might be better adapted to the operating requirements than a stop-log structure. A gated dam or a dam with a movable crest may be necessary because of the need for effective control with only small fluctuations in stage.

Backwater Effects

The dam at Days High Landing would control the water surface levels in the vicinity of White Oak Lake and Little White Oak Lake during low stages in the Pokegama pool and during low discharges at Days High Landing. Days High Landing Dam would not reduce the effective storage of Pokegama Lake. To be most beneficial, the Days High Landing pool must be maintained at a level that causes minimum backwater effects upstream. Elevation 1279.0 represents the upper reasonable elevation of the pool at White Oak Point. At Deer River this pool elevation would represent an elevation of about 1279.0 which would allow the sewage system for the community to function normally.

The existing dam at the outlet of Mud Lake stabilizes the level of Mud and Goose Lakes. With a discharge of 1,300 cfs on the Leech Lake River or a discharge of 1,500 cfs on the Mississippi River, the control capacity or elevation 1280.5 is exceeded at Mud Lake Dam. An elevation of 1279.0 and a discharge of 400 cfs at Days High Landing would produce an elevation of 1280.3 at Willow Beach at the mouth of the Leech Lake River. The elevation of 1280.3 at Willow Beach would be reached once in about 7 years during June and July. The dam is designed to cause only minor adverse effects from backwater at Ball Club Lake, Willow Beach, and Mud Lake Dam. With a discharge of 4,000 cfs at Days High Landing and a stage of 12.00 at Pokegama Dam, the backwater effect would be 0.06 foot at Willow Beach and 0.10 foot at Ball Club Lake. The following table shows the backwater effect at Willow Beach caused by the proposed Days High Landing Dam with a pool elevation of 1279.0 at White Oak Point. At maximum flow conditions, backwater effects at Willow Beach would be minor, but the slope in the pool between Days High Landing and Willow Beach would be considerable. The water surface profile between Days High Landing and Willow Beach and between Pokegama Dam and Days High Landing under natural conditions is shown on plate A-80.

Backwater effect at Willow Beach

Discharge (cfs)	Pokegama stage (feet)	Elevation at Willow Beach without dam (USE datum)	Elevation at Willow Beach with dam (USE datum)	Backwater (feet)
0	9.25	1274.52	1279.00	4.48
1,000	9.25	1277.88	1280.50	2.62
2,000	9.25	1280.28	1281.17	0.89
2,500	9.25	1281.14	1281.38	0.24
2,700(1)	9.25	1281.63	1281.60	0.03
4,000	12.00	1283.57	1283.63	0.06
6,000	12.00	1284.63	1284.67	0.04

(1) When discharges exceed 2,700 cfs at a Pokegama stage of 9.25 feet, Days High Landing Dam would be drowned out, and elevation 1279.0 would be exceeded at White Oak Point. Under these conditions, control would revert to Pokegama Dam. A Pokegama stage of 9.25 feet is the maximum desirable summer stage.

Freeboard

The freeboard for the tieback dikes was determined in accordance with criteria in Engineer Circular 1110-2-27 and Engineer Technical Letter 1110-2-8. The top elevation of 1283.0 for the left bank dike was determined by using a pool at elevation 1279.0 with 60-mile-per hour winds and the required freeboard allowance equal to the resulting wave height for shallow inland lakes. The top elevation of 1285.5 for the right bank dike is required for access to the control structure service bridge.

Swellhead Curves at Proposed Days High Landing Dam

The swellheads caused by the proposed dam at Days High Landing were computed for 6- and 12-foot stages at Pokegama Dam and are shown as curves on plate A-81. The two curves for the swellhead at Days High Landing Dam were computed using the D'Aubuisson's formula for the increase in head caused by channel obstruction. The "K" coefficient used was 0.85 since the dam would produce a relatively small amount of channel contraction compared to the improved channel immediately upstream. As can be observed from the curves, the swellhead would be less than 0.10 foot until the flow approaches 4,000 cfs and 0.20 foot with a flow of 6,000 cfs. Flow conditions are represented with all stop logs removed and all flow passing through the dam.

COST ESTIMATE

A detailed cost and benefit analysis is included in the March 1972 interim survey report for Days High Landing Dam. The cost summary from the 1972 report (1971 price levels) follows along with the costs and benefits indexed to October 1977 values.

Estimated first costs for Days High Landing Dam (1971 prices)

[illegible]	Unit	[illegible]	[illegible]	Total estimated cost
[illegible]				
Fee title	Ac	[illegible]	[illegible]	[illegible]
[illegible]	Ac	[illegible]	[illegible]	[illegible]
[illegible]	Job		[illegible]	[illegible]
[illegible]	Job		[illegible]	[illegible]
[illegible]				[illegible]
[illegible]				79,[illegible]
[illegible]				
[illegible]	Ac	8	[illegible]	[illegible]
[illegible]	CY	[illegible]	[illegible]	[illegible]
[illegible]	CY	[illegible]	1.00	[illegible]
[illegible]				
[illegible]	CY	9,000	[illegible]	[illegible]
[illegible]	CY	[illegible]	[illegible]	[illegible]
[illegible]	CY	[illegible]	1.85	[illegible]
[illegible]	CY	[illegible]	[illegible]	[illegible]
[illegible]				
[illegible]	CY	[illegible]	[illegible]	[illegible]
[illegible]	CY	[illegible]	[illegible]	[illegible]
[illegible]	CY	[illegible]	[illegible]	[illegible]
Filter	CY	[illegible]	[illegible]	[illegible]
Topsoil	CY	[illegible]	[illegible]	[illegible]
Seeding	Ac	[illegible]	[illegible]	[illegible]
Concrete				
Slab, key, and sill	CY	1,590	50.00	79,500
Piers	CY	350	70.00	24,500
[illegible]	CY	500	[illegible]	[illegible]
[illegible]	Bbl	3,[illegible]	[illegible]	[illegible]
Reinforcing steel	Lb	[illegible]	[illegible]	[illegible]
[illegible]				
inch with floor stand)	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LF	[illegible]	[illegible]	[illegible]
[illegible]	LF	[illegible]	[illegible]	2,[illegible]
[illegible]	[illegible]	10	[illegible]	[illegible]
[illegible]	[illegible]	675	[illegible]	[illegible]
[illegible]	Lb	41,400	[illegible]	[illegible]
[illegible]	SF	190	8.50	[illegible]
[illegible]				
[illegible]	LF	550	5.50	3,[illegible]
[illegible]	[illegible]	[illegible]	1.50	[illegible]
[illegible]				
8-f[illegible])	Job	Sum		3,000
[illegible]	[illegible]	Sum		[illegible]
[illegible]	Job	Sum		[illegible]
[illegible]				
[illegible]	Job	[illegible]		[illegible]
[illegible]	Job	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]				[illegible]
[illegible]				[illegible]

Estimated first costs for Days High Landing Dam (1971 prices) (cont)

Item	Unit	Quantity	Unit cost	Total estimated cost
[illegible]				
[illegible]				
[illegible]	[illegible]	[illegible]	[illegible].00	[illegible]
[illegible]	[illegible]	[illegible]	0.90	[illegible]
[illegible]	[illegible]	[illegible]	[illegible].00	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]
[illegible]			[illegible]	[illegible]
[illegible]				[illegible]
[illegible]				[illegible]
[illegible] facilities				
Three new [illegible] sites	[illegible] sum		[illegible],000.00	[illegible]
[illegible] (docks, [illegible], etc.)	[illegible] sum		[illegible]	[illegible]
[illegible] existing access [illegible]	[illegible] sum		[illegible],000.00	[illegible]
[illegible]				[illegible]
[illegible]				[illegible]
[illegible] design				[illegible]
[illegible] administration				
[illegible] and [illegible]				[illegible]
[illegible]				[illegible]
[illegible] supervision and administration				[illegible]
[illegible] first cost				[illegible]

[illegible] Exclusive of [illegible] authorization study costs, [illegible].

BENEFITS

A benefit-cost summary was prepared which compares the benefits developed in the 1972 interim survey report with benefits based on October 1977 price levels. Revised benefits were developed with the aid of the Minnesota Department of Natural Resources. The comparison is shown in the following table.

Benefit-cost summary, Days High Landing Dam (White Oak Lake)

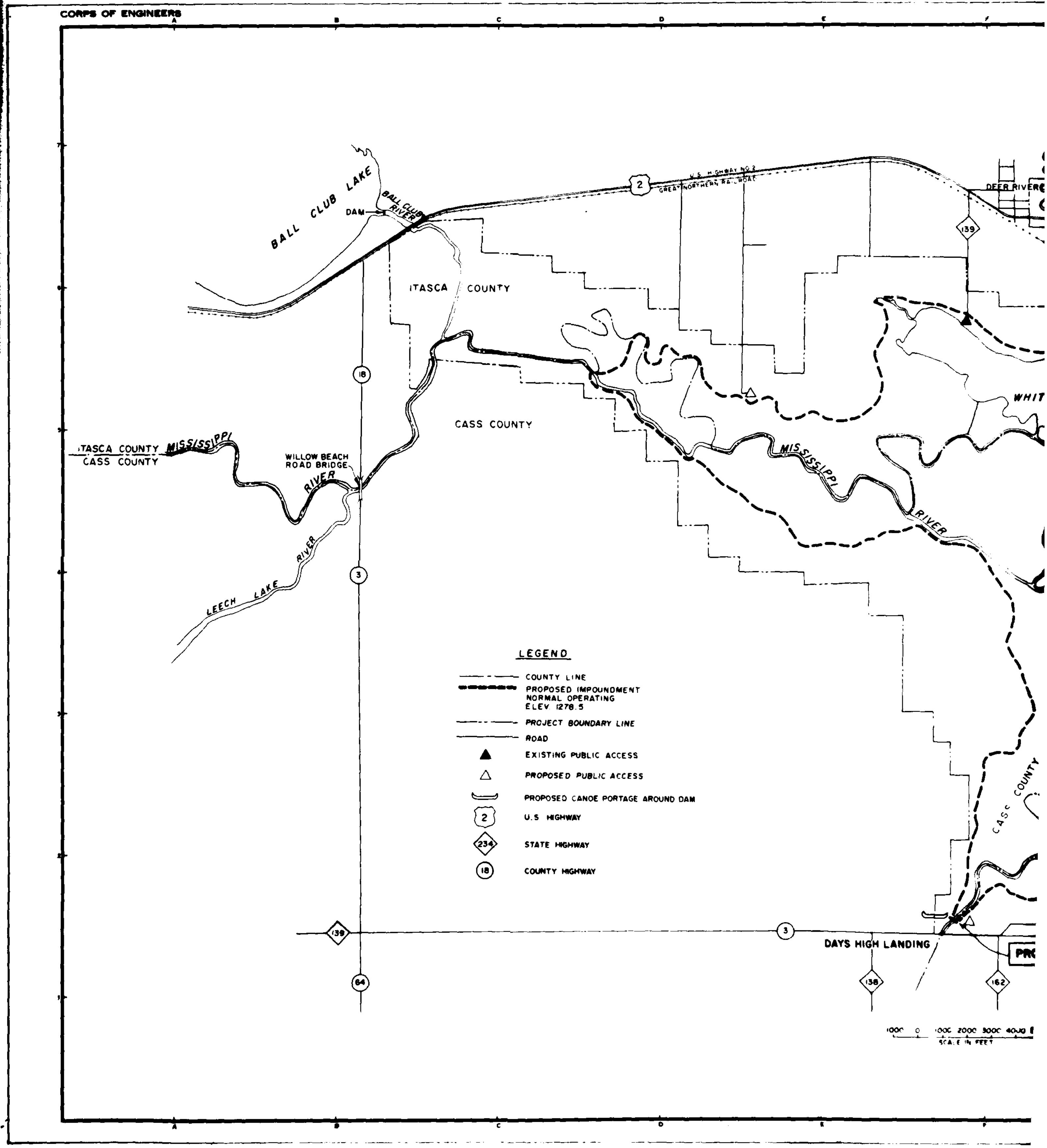
Item	Amount 1971 prices	1977 prices	1981 prices
First cost	$1,439,000	$2,160,000	$2,894,000
Annual cost	93,500	164,300	249,000
Annual benefits			
Increased wild rice production	176,000	250,000	-
Increased fishery resources	22,000	31,200	-
Increased waterfowl production	7,000	9,950	-
Increased furbearer production	9,000	12,925	-
Area redevelopment	9,000	12,925	-
Total annual benefits	223,000	317,000	425,000
Benefit-cost ratio	2.4	1.93	1.71
Interest rate (percent)	5 3/8	6 5/8	7 5/8

RECOMMENDED ACTION

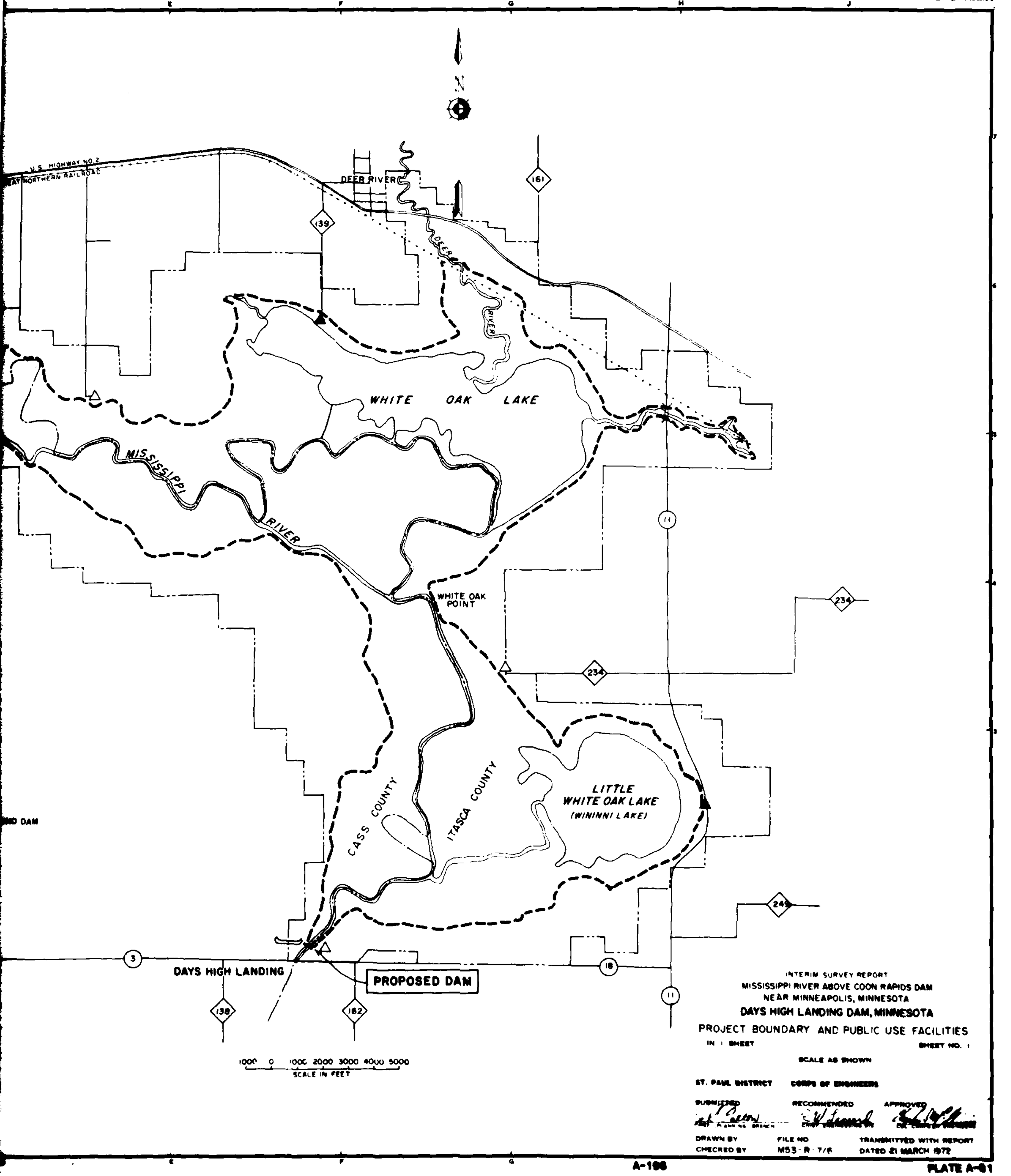
No further action is recommended for stabilizing the White Oak Lake water levels. A proposed dam at Days High Landing is economically feasible and would help stabilize White Oak Lake levels, but the Minnesota Department of Natural Resources is opposed to this development. A detailed study and interim survey report were completed in March 1972 for the White Oak Lake area, and a portion of the design information developed for that study is contained in this report.

PLATE SUMMARY

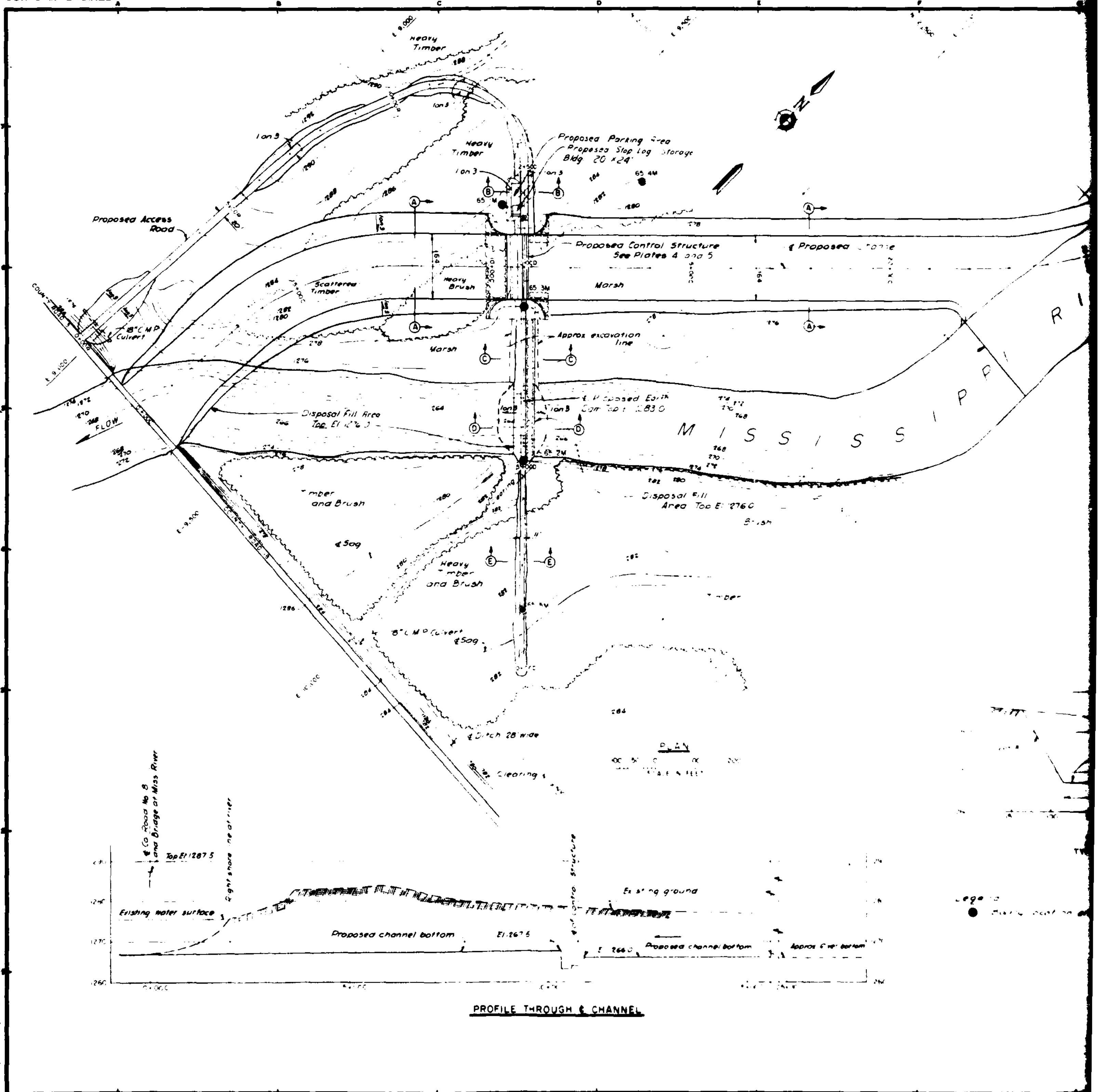
Number	Item
A-81	Days High Landing Dam, Minnesota, project boundary and public use facilities.
A-82	Plan and profile.
A-83	Boring logs and sections.
A-84	High discharge-frequency curve.
A-85	High stage-frequency curves.
A-86	Low stage-frequency curves.
A-87	Pokegama flowage, water surface profiles
A-88	Swellhead curves



CORPS OF ENGINEERS
BALL CLUB LAKE
DAM
BALL CLUB RIVER
U.S. HIGHWAY NO. 2
GREAT NORTHERN RAILROAD
DEER RIVER
ITASCA COUNTY
CASS COUNTY
ITASCA COUNTY
CASS COUNTY
MISSISSIPPI
RIVER
WILLOW BEACH
ROAD BRIDGE
LEECH LAKE RIVER
MISSISSIPPI
RIVER
WHIT
CASS COUNTY
DAYS HIGH LANDING
LEGEND
COUNTY LINE
PROPOSED IMPOUNDMENT
NORMAL OPERATING
ELEV. 1278.5
PROJECT BOUNDARY LINE
ROAD
EXISTING PUBLIC ACCESS
PROPOSED PUBLIC ACCESS
PROPOSED CANOE PORTAGE AROUND DAM
U.S. HIGHWAY
STATE HIGHWAY
COUNTY HIGHWAY
SCALE IN FEET


N
U.S. HIGHWAY NO. 2
NORTHERN RAILROAD
DEER RIVER
DEER RIVER
WHITE OAK LAKE
MISSISSIPPI RIVER
WHITE OAK POINT
CASS COUNTY
ITASCA COUNTY
LITTLE WHITE OAK LAKE
(WININNI LAKE)
DAYS HIGH LANDING
PROPOSED DAM
1000 0 1000 2000 3000 4000 5000
SCALE IN FEET
INTERIM SURVEY REPORT
MISSISSIPPI RIVER ABOVE COON RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA
PROJECT BOUNDARY AND PUBLIC USE FACILITIES
IN 1 SHEET
SHEET NO. 1
SCALE AS SHOWN
ST. PAUL DISTRICT
CORPS OF ENGINEERS
SUBMITTED
RECOMMENDED
APPROVED
DRAWN BY
CHECKED BY
FILE NO
M53-R-7/6
TRANSMITTED WITH REPORT
DATED 21 MARCH 1972

CORPS OF ENGINEERS



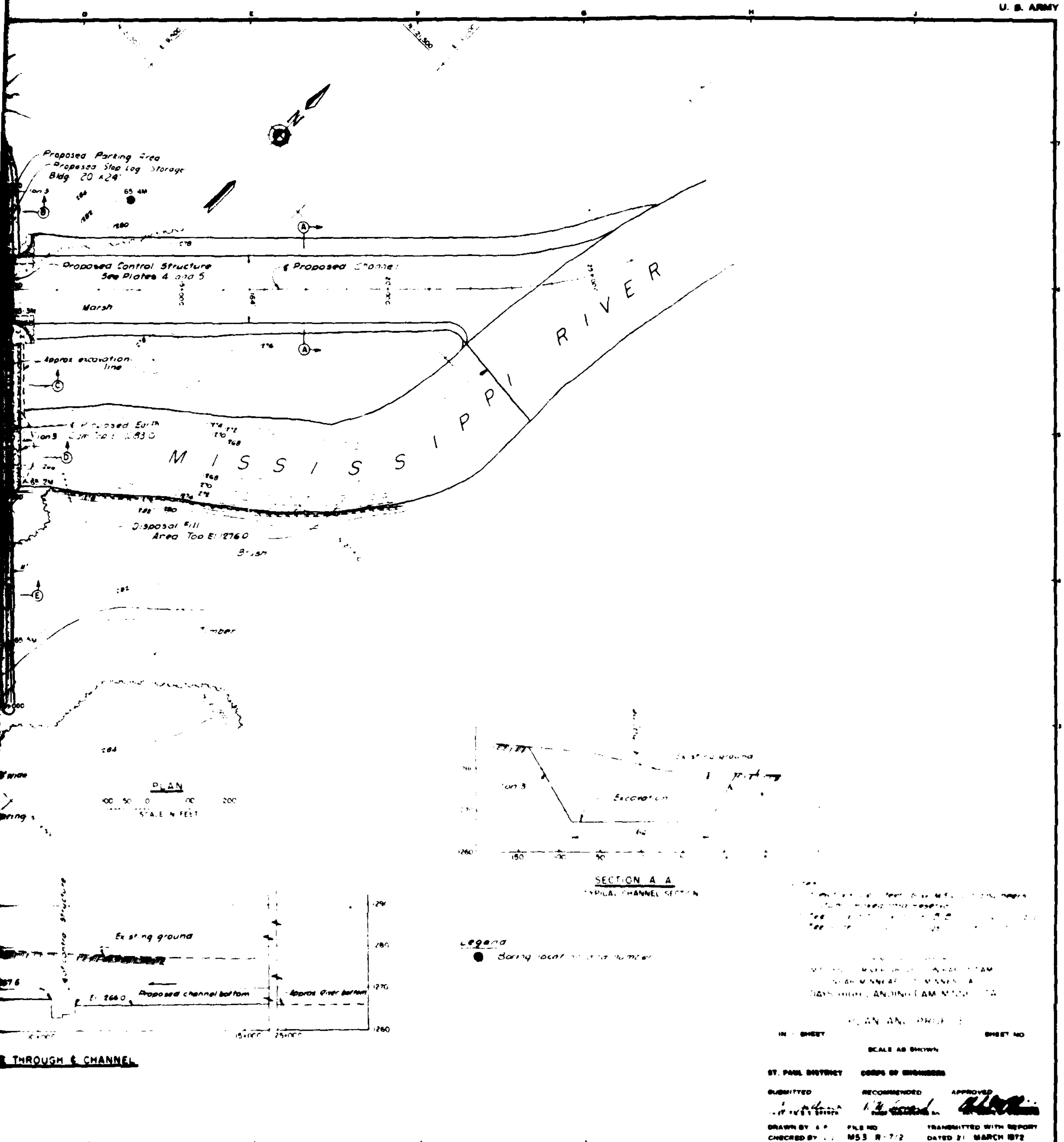
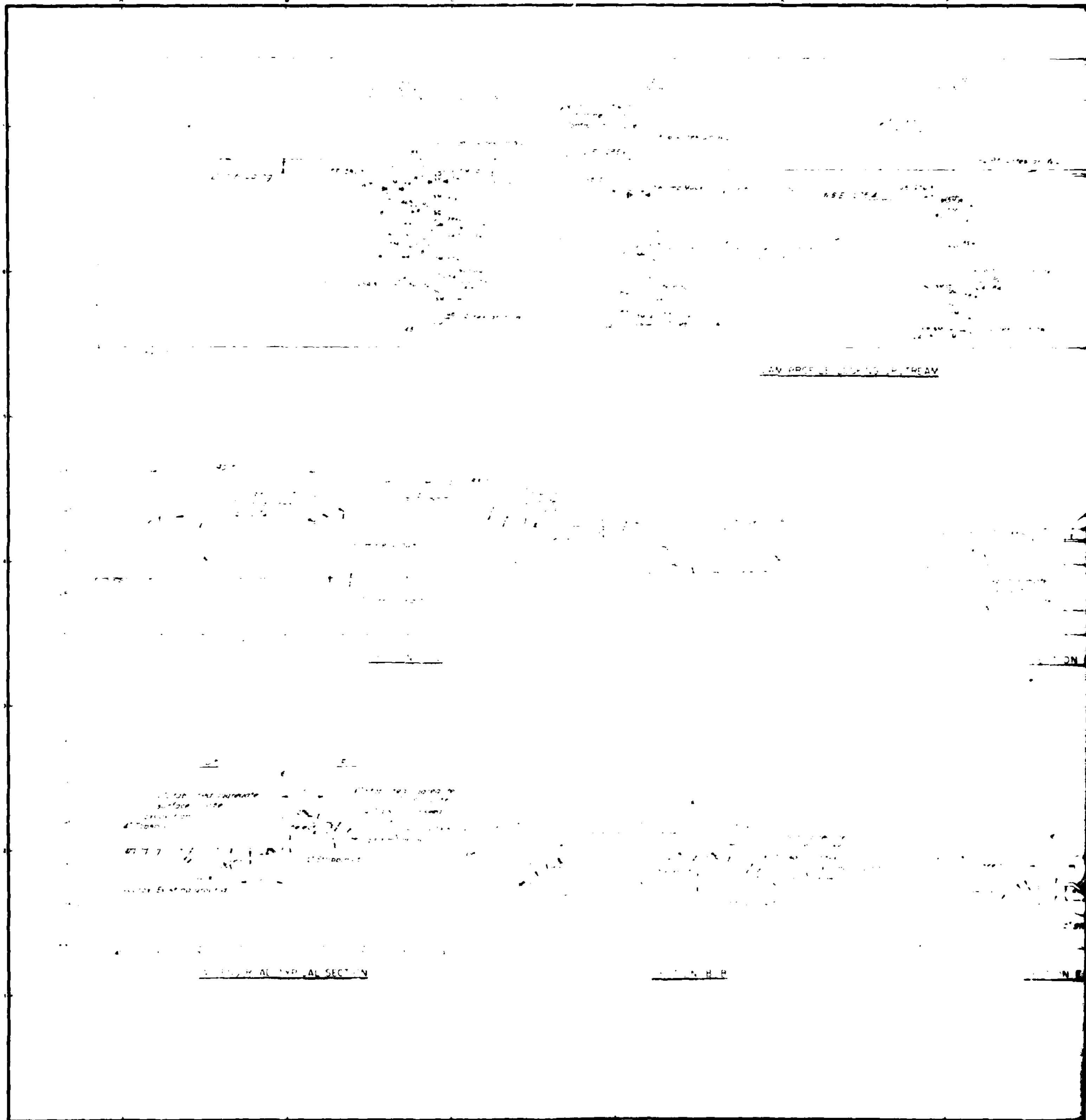

U. S. ARMY
Proposed Parking Area
Proposed Stop Log Storage Bldg 20' x 24'
Proposed Control Structure
See Plates 4 and 5
Proposed Channel
Marsh
Approx excavation line
Proposed Earth
MISSISSIPPI RIVER
Disposal Fill
Area Top El 1276.0
Brush
Timber
PLAN
SCALE IN FEET
SECTION A-A
TYPICAL CHANNEL SECTION
Existing ground
Excavation
Existing ground
Proposed channel bottom
Approx River bottom
THROUGH ℄ CHANNEL
Legend
Boring location
PLAN AND PROFILE
SCALE AS SHOWN
ST. PAUL DISTRICT
CORPS OF ENGINEERS
SUBMITTED
RECOMMENDED
APPROVED
DRAWN BY
CHECKED BY
FILE NO
M53 R-7/2
TRANSMITTED WITH REPORT
DATED 21 MARCH 1972

PLATE A-82

CORPS OF ENGINEERS



U. S. ARMY

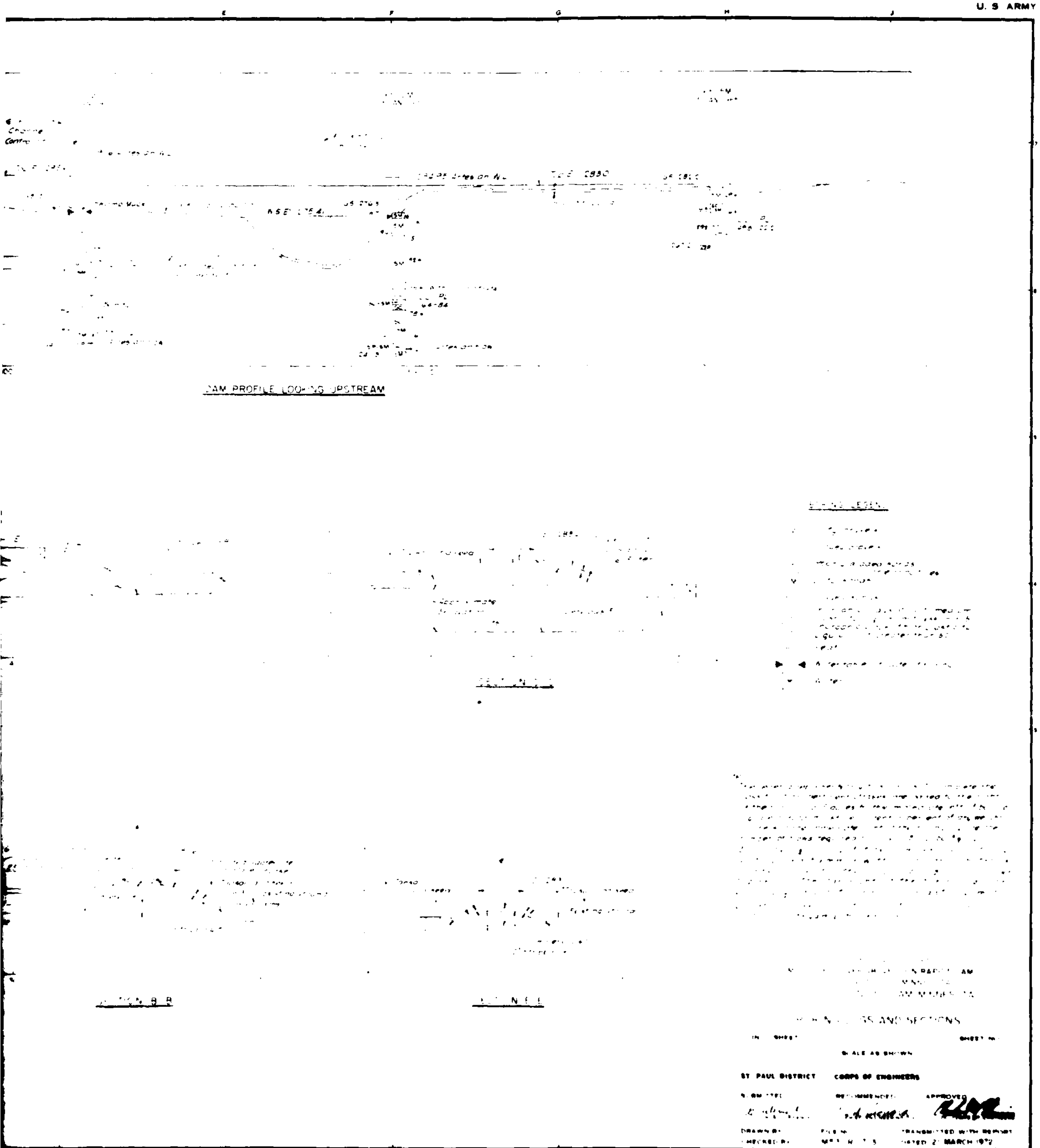
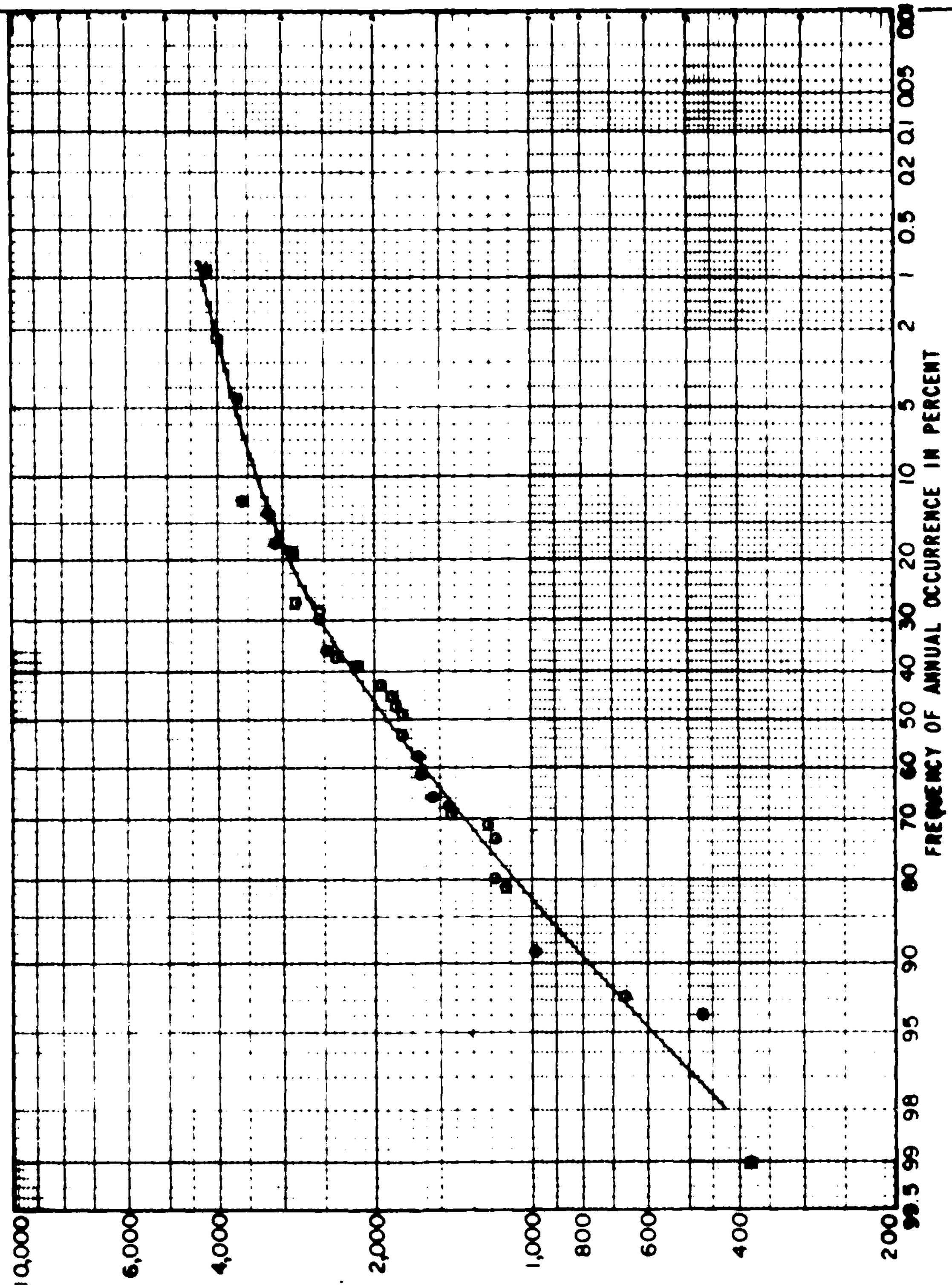


PLATE A-83



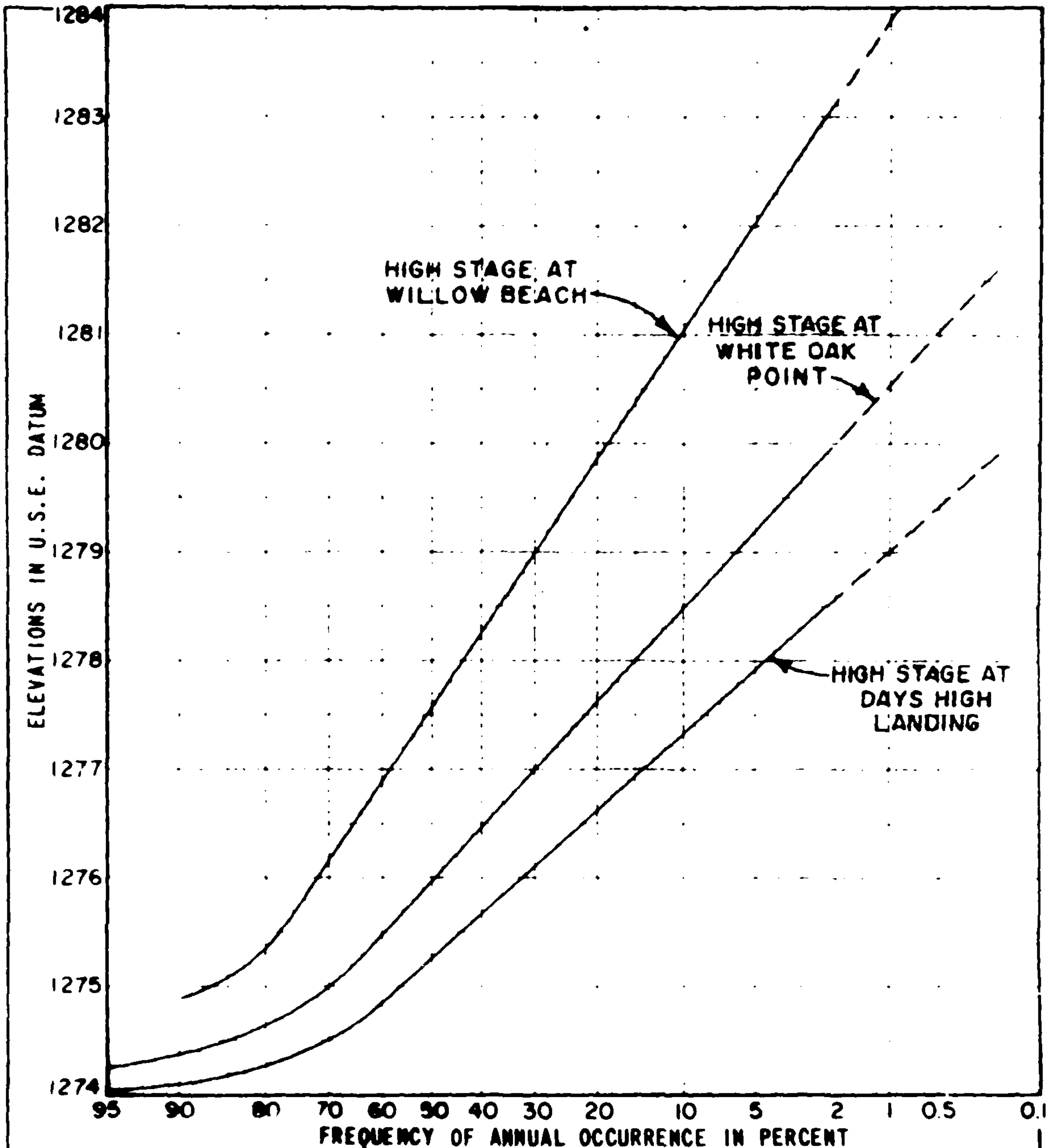
NOTE:

HIGH DISCHARGE FREQUENCY CURVE, MISSISSIPPI RIVER AT DAYS HIGH LANDING. 32 YEARS OF COMPUTED RECORDS (1930 THRU 1961) ADJUSTED TO 77 YEARS OF RECORDS (1885 THRU 1961).

INTERIM SURVEY REPORT
MISSISSIPPI RIVER ABOVE COON RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA

HIGH DISCHARGE FREQUENCY CURVE

ST. PAUL, MINN. DISTRICT
FILE NO. M53-R-7/12 2' FEB 1970



NOTES:

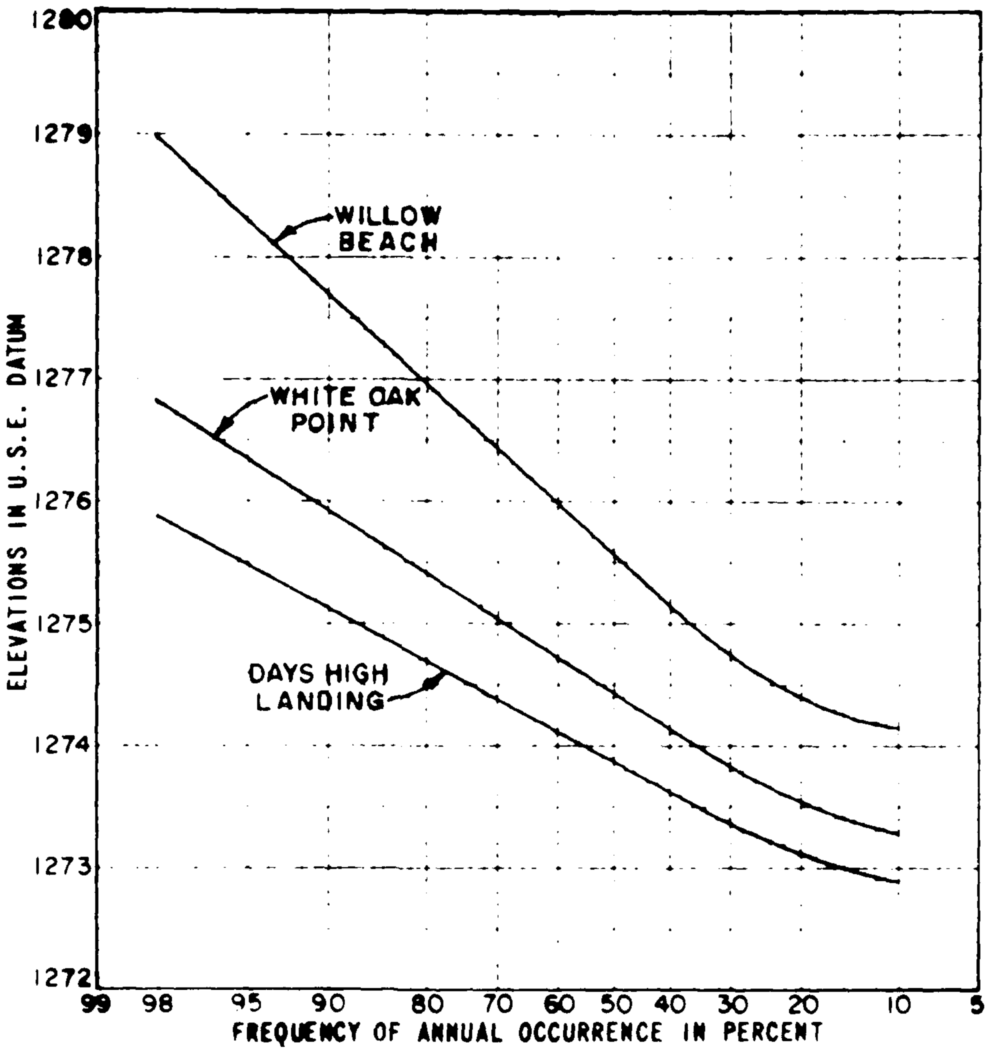
HIGH STAGE FREQUENCY CURVES FOR JUNE AND JULY FROM DISCHARGE HYDROGRAPHS FOR POKEGAMA FLOWAGE FOR YEARS 1943 THRU 1961 ADJUSTED TO YEARS 1930 THRU 1961.

POKEGAMA GAGE ZERO = 1265.27 U.S.E.D.
= 1264.42
1929 adj

INTERIM SURVEY REPORT
MISSISSIPPI RIVER ABOVE COON RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA

HIGH STAGE FREQUENCY CURVES

ST. PAUL, MINN. DISTRICT
FILE NO. M 5[illegible]-R-7/13 20 FEB 1970



NOTES:

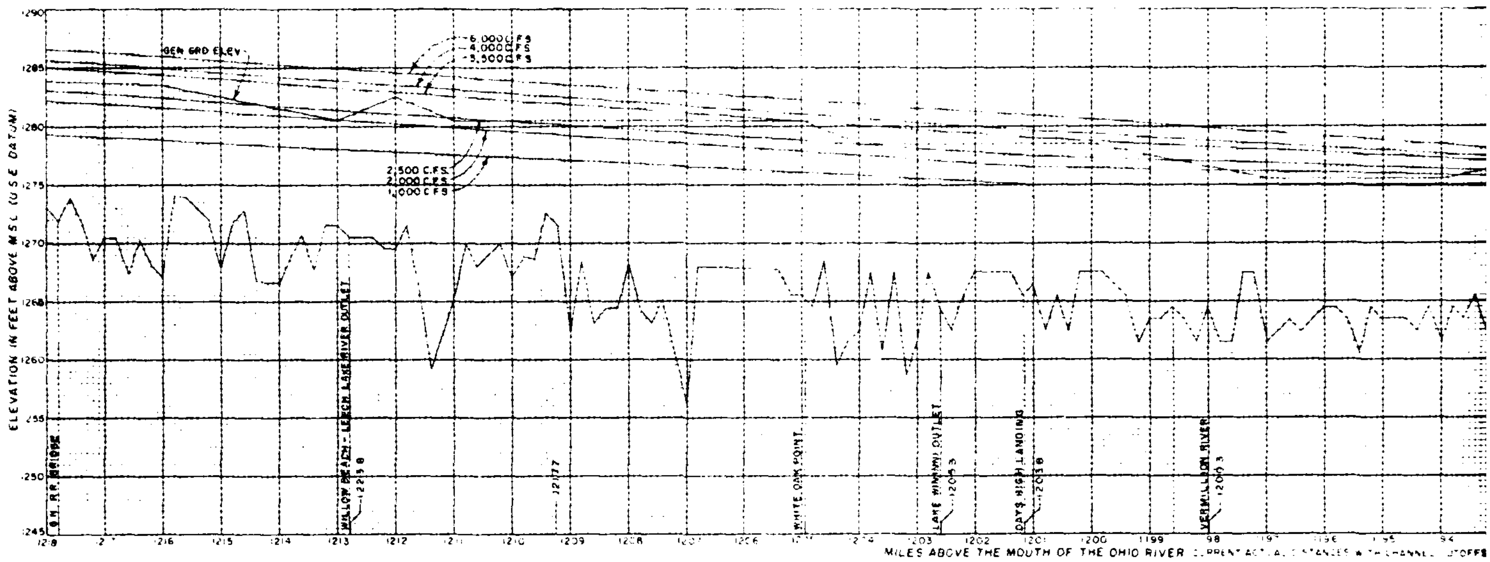
LOW STAGE FREQUENCY CURVES FOR JUNE AND JULY FROM DISCHARGE HYDROGRAPHS FOR POKEGAMA FLOWAGE FOR YEARS 1943 THRU 1961 ADJUSTED TO YEARS 1930 THRU 1961.

POKEGAMA GAGE ZERO = 1265.27 U.S.E.D.
= 1264.42 (1929 adj)

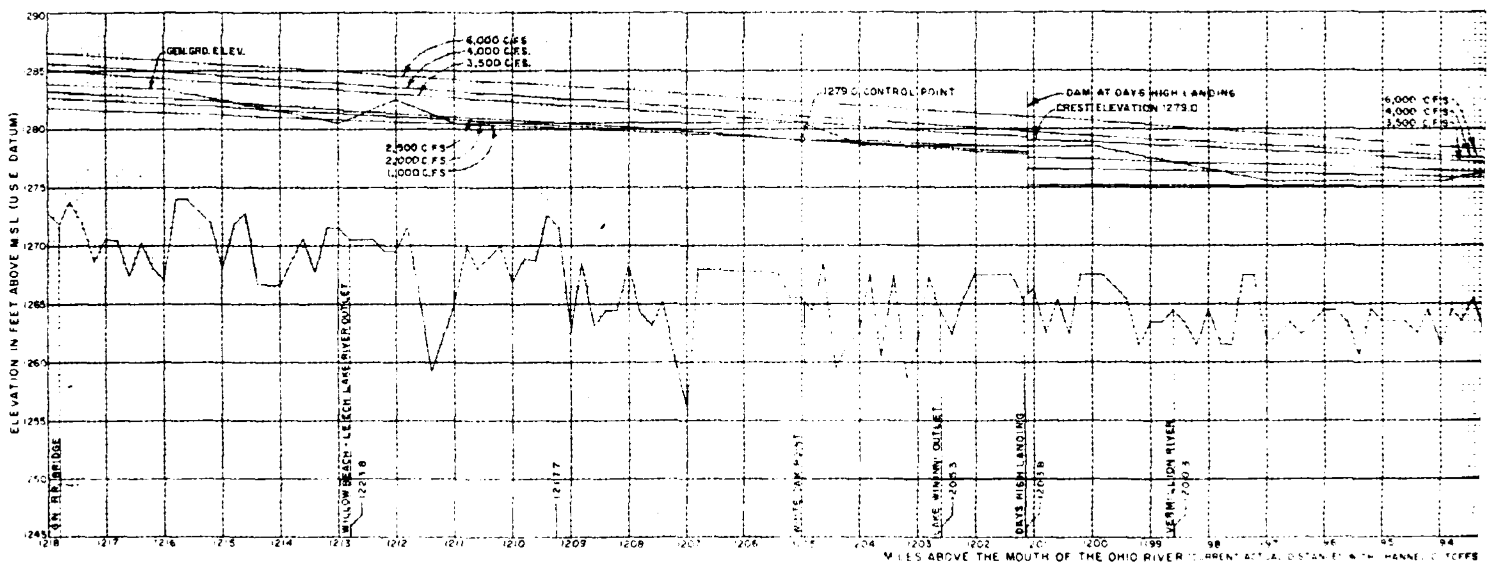
INTERIM SURVEY REPORT
MISSISSIPPI RIVER ABOVE COON RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA

LOW STAGE FREQUENCY CURVES

ST. PAUL, MINN. DISTRICT
FILE NO. M53-R-7/14 20 FEB 1970



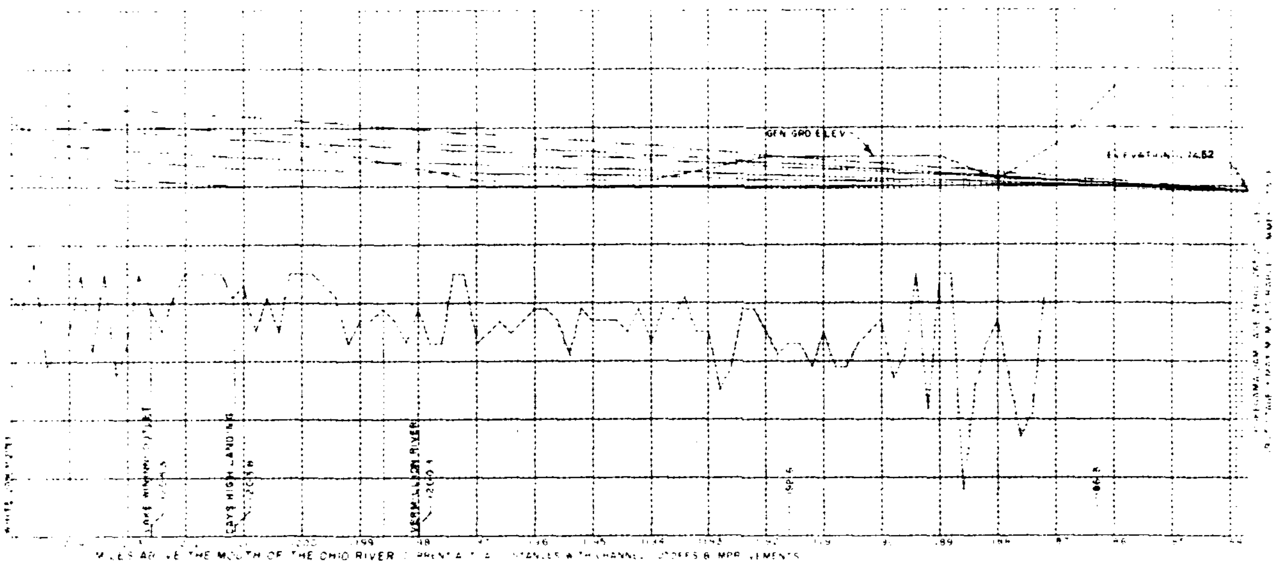
WATER SURFACE PROFILES FOR EXISTING CONDITIONS



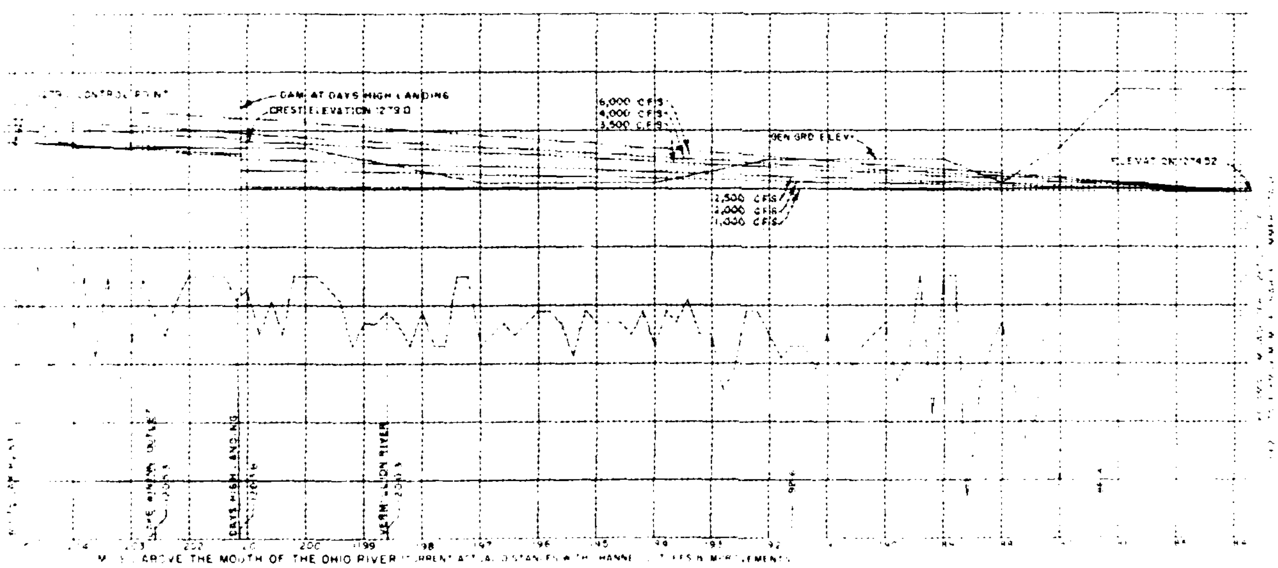
WATER SURFACE PROFILES FOR PROPOSED CONDITIONS

NOTE
THE UPPER
THE NATURAL CH
CHANNEL CUTOFF

U S ARMY



WATER SURFACE PROFILES FOR EXISTING CONDITIONS



WATER SURFACE PROFILES FOR PROPOSED CONDITIONS

NOTE
THE UPPER MILEAGE SCALE REPRESENTS THE NATURAL CHANNEL MILEAGE BEFORE THE CHANNEL CHANGES IN IMPROVEMENTS

MISSISSIPPI RIVER ABOVE ... RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA
POKEGAMA FLOWAGE
WATER SURFACE PROFILES

IN 1 SHEET | SHEET NO

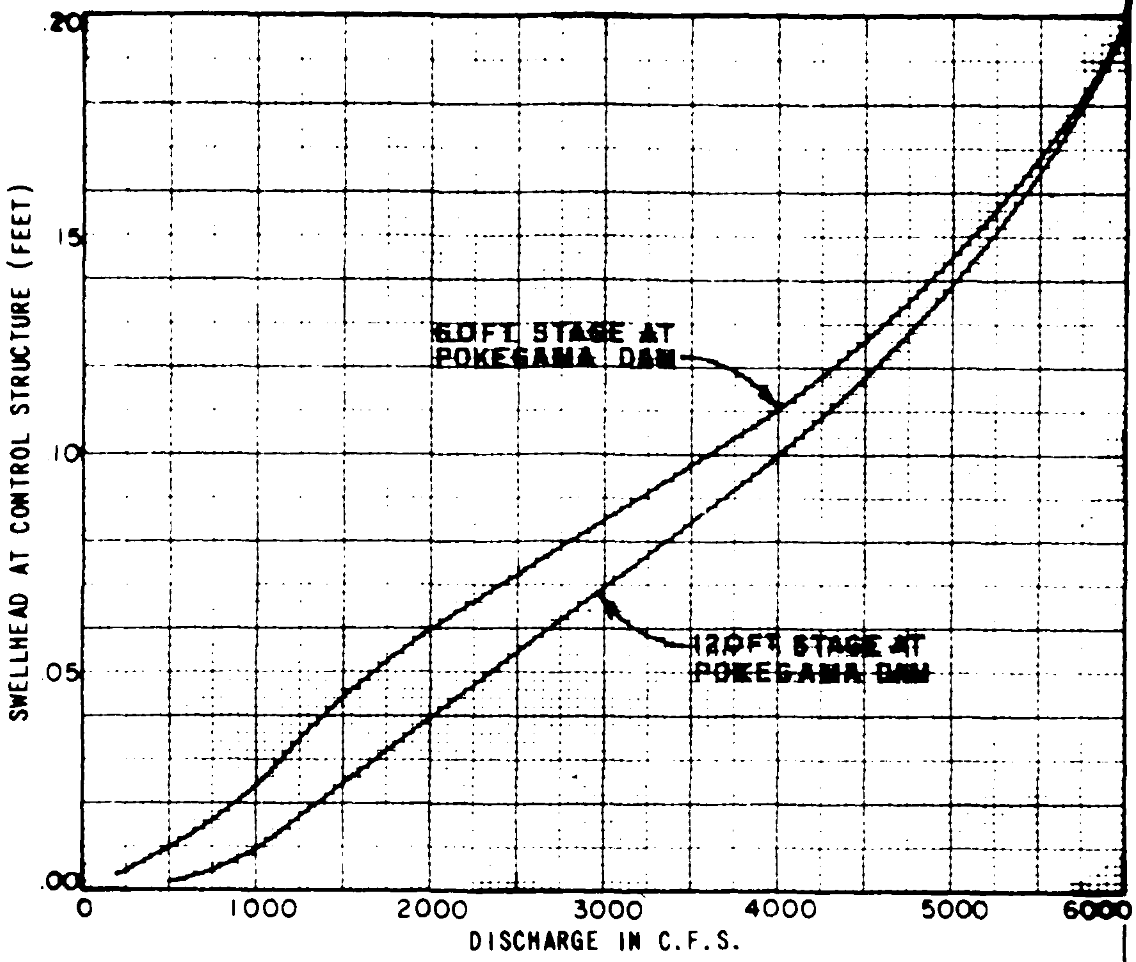
SCALE AS SHOWN

ST. PAUL DISTRICT CORPS OF ENGINEERS

SUBMITTED | RECOMMENDED | APPROVED

DRAWN BY | FILE NO | TRANSMITTED WITH REPORT
CHECKED BY | M53 R | DATED FEBRUARY 19

PLATE A-87



NOTE:

SWELLHEAD CURVES FOR CONTROL STRUCTURE AT DAYS HIGH LANDING ALL STOPLOGS REMOVED AND ALL FLOW THROUGH THE STRUCTURE.

INTERIM SURVEY REPORT
MISSISSIPPI RIVER ABOVE COON RAPIDS DAM
NEAR MINNEAPOLIS, MINNESOTA
DAYS HIGH LANDING DAM, MINNESOTA

SWELLHEAD CURVES

ST. PAUL, MINN. DISTRICT
FILE NO. M53-R-7/18 20 FEB 1970

PROBLEM 5 - BLACK BEAR AND MILLER LAKES FLOOD PROBLEM

BACKGROUND

Black Bear and Miller Lakes are located adjacent to the Mississippi River in Crow Wing County, Minnesota. The lakes are located in portions of sections 30 and 31, T 147 N, R 29 W; section 36, T 147 N, R 30 W; section 6, T 146 N, R 29 W; and section 1, T 146 N, R 30 W. The two lakes have a combined surface area of approximately 320 acres and are connected to the Mississippi River by a creek approximately one-half mile long. The location of the lakes is shown on plate A-82.

Mississippi River flooding has affected approximately 28 lake properties in 1974 and 1975. Spring high water on the Mississippi River backs up the creek channel, overtopping the stop log bays and abutments of an old Work Projects Administration dam located in the creek channel downstream of the two lakes. The backup water floods the shoreline properties causing damage to buildings and related facilities.

The Minnesota Department of Natural Resources has advised the affected residents that the situation is a natural occurrence and does not adversely affect the general public's interest. Therefore, Department funds could not be used to reduce flooding.

GEOLOGY AND SOILS

No formal program of subsurface investigations was conducted for the potential damsite at the outlet of Black Bear Lake. The soil in the area is classified as Menagha, a type having a high infiltration rate, as discussed under Hydrology and Hydraulic Studies. The Menagha soil is in a group of coarse to medium textured forest soils formed from glacial outwash.

HYDROLOGY AND HYDRAULIC STUDIES

Preliminary hydrology and hydraulic studies confirmed that the principal flood problem of the Black Bear and Miller Lakes properties results from the Mississippi River and not from the local contributing drainage area (see plate A-82, drainage basin map, and plate A-83, location map). During high water the Mississippi River backs into the Black Bear and Miller Lakes area, producing flood levels which inundate approximately 28 of 38 lakeshore residential properties. The lowest ground level elevation of cabins and residences on Black Bear and Miller Lakes, with respect to flood and other pertinent levels, is shown on the following figure.

BLACK BEAR AND MILLER LAKES ELEVATION HISTORY

1170 ELEV. TO 1200 ELEV.[1]

HIGHEST ELEVATION OF DRAINAGE AREA 1200

PROPOSED NEW DIKE ELEVATION 1190

1186.5
HIGH WATER - 1950

HIGH WATER - 1965, 69,75 1183.7

CRITICAL LEVEL OF UNITS 1179

BLACK RIVER & MILLER LAKES NORMAL LEVEL 1177

LOW WATER 1901 1173.7

CREEK BOTTOM 1170

(1) Approximate levels for estimation purposes in M.S.L. (1929 adj.)

Flood elevations and related damages were determined by relating preliminary field survey information of area water levels and lake properties to flood profiles of the Mississippi River, shown on plate A-84. On this plate, the Black Bear outlet to the Mississippi River is at mile 164.9 above Minneapolis. Frequency of floods was further developed from flood events at Aitkin, approximately 38 miles upstream on the Mississippi River at mile 202.9 above Minneapolis. A tabulation showing this relationship follows.

Elevations and frequency of floods

Year	Elevation(1) river mile 164.9	Flow (cfs)	Aitkin, (river mile 202.9) recurrence interval (years)	Percent chance exceedence
1950	1186.5	20,000	100+	<1
1965	1183.4	13,400	13	7.7
1969	1183.7± (estimated)	14,400	13	7.7
1975	1183.7± (estimated)	14,300	13	7.7
1889	1175.7	-	-	-
1901	1173.7 (low water)	-	-	-
1899	1163.9 (thalweg)	-	-	-

(1) Elevations are 1929 adjustment which is approximately 0.3 foot lower than msl, 1912 adjustment, shown on plate A-84.

Additional hydrologic work was accomplished to determine if a pumping station would be required in the event a new levee was built in the outlet channel from Black Bear Lake to the Mississippi River. The purpose of this levee would be to prevent the Mississippi River from backing into Blear Bear and Miller Lakes during floods. Runoff from the local drainage area contributing to Black Bear and Miller Lakes had to be evaluated to see if it posed a flood threat to local property owners in the event a levee were holding back the Mississippi River flows. The anticipated Mississippi River stages during high water periods could require a levee closure for a 2- to 4-week period.

The additional hydrology studies involved drainage area determination and preliminary calculations of 25-year runoff volume. Runoff peaks and volumes were derived using families of curves developed by the Soil Conservation Service for small areas as outlined in Minnesota Engineers Handbook, section 4 on hydrology.

The total drainage area contributing to the Black Bear and Miller Lakes area (plate A-82) is approximately 5,440 acres (8.5 square miles). The general soil type for calculation of runoff is Menagha or group A. Group A soils have high infiltration rates even when thoroughly wetted and consist chiefly of deep, well to excessively drained sands and/or gravel. These soils have a high rate of water transmission and would result in a low runoff potential (minimum infiltration rate: 0.30 to 0.45 inch per hour). A Soil Conservation Service runoff curve number of 55 was selected to represent a watershed which is wooded and has good field cover.

The time of concentration for the watershed was determined next from a Soil Conservation Service nomograph using total watershed vertical drop (30 feet) and the longest travel distance in the watershed (17,500 feet). The resulting time of concentration was 2.8 hours. Therefore, a design storm duration of 6 hours was used to evaluate 25-year (4-percent) runoff potential for the watershed using precipitation derived from National Weather Service publication T.P. 40. Point rainfall for a 6-hour storm was 3.25 inches and was not reduced because of the small (8.5-square mile) contributing drainage area.

The area requiring protection is identified as class III (EM 1110-2-1410, paragraph 3-05) and the gravity outlet design is based on the runoff from the 25-year storm. The 25-year runoff volume for a 6-hour, 3.25-inch rainfall and a runoff curve number of 55 amounts to 200 acre-feet from an 8.5-square mile drainage area. The 200 acre-feet of runoff would produce a rise in the Black Bear-Miller Lakes water surface of about 0.6 foot or from normal elevation 1177.0 to elevation 1177.6.

The 0.6-foot rise would produce an estimated 26-cfs peak outflow through the old WPA dam that controls the normal lake level. This dam has two 5-foot stop log bays with the center pier and top of stop logs at approximately elevation 1176.8. A 30-inch diameter outlet in the proposed new levee downstream from the State dam would satisfactorily handle the 26-cfs discharge on a slope of 0.0033 and with a head of 1.3 feet above the Mississippi River stage.

With a normal elevation of 1177 in Black Bear and Miller Lakes, it was decided that no pumping facilities would be needed in a control levee that would block Mississippi River water from backing into Black Bear and Miller Lakes. A 1-foot rise to elevation 1178 with no flood damages could easily be tolerated by lakeshore owners, and the anticipated 0.6-foot rise from a 25-year storm would not require pumping.

COST ESTIMATE

An economically feasible project was developed for the Black Bear and Miller Lakes flood problem. The most economical structural solution would be to construct a rolled earth-fill levee on the unnamed stream that leads from Black Bear Lake to the Mississippi River. This alternative is economically feasible with a first cost of $128,000, an annual cost of $11,000 including operation and maintenance, and an annual benefit of $13,400. The resulting benefit-cost ratio is 1.22. The costs and benefits for a levee alternative are shown in the following table. In contrast, the annual cost for nonstructural federally subsidized flood insurance is estimated at $7,200 for insuring affected lake property units.

Detailed estimate of construction costs (1977 prices)

Item	Unit	Quantity	Unit cost	Total cost
Federal first costs				
Construction				
30-inch, class 4 RCP conduit	Feet	135	$30.00	$4,050
20-10c slide gate, rack, and frame	Each	1	4,500.00	4,500
Concrete gate well	Each	1	5,600.00	5,600
Metal ladder	Feet	20	12.50	250
Cutoff excavation	CY	530	0.70	370
Disposal	CY	530	1.50	800
Impervious fill	CY	530	3.00	1,600
Compacted fill	CY	6,250	6.00	37,500
Stripping	CY	40	3.00	120
Dewatering	Job	Sum	-	14,450
Total construction				69,240
Contingencies				13,860
Engineering and design				6,250
Supervision and administration				6,250
Total Federal first costs				95,600
Non-Federal first costs - Lands (transfer of State ownership)	Acre	1.0	(1)	(1)
Total first cost				95,600
Annualized first cost (6 5/8-percent interest and 100-year life = 0.06636 x $95,600)				6,400
Annual operation and maintenance cost				800
Total average annual cost				7,200
Total average annual benefits (2)				10,000
Benefit-cost ratio				1.39

(1) State of Minnesota has not provided a land value. A permit to construct may be used in lieu of a land transfer.
(2) Benefits were derived as described under the following section on benefits.

The following table summarizes the pertinent figures from the previous table at 1977 and 1981 price levels.

Benefit-cost summary - proposed closure structure

Item	1977 prices	1981 prices
First cost	$95,600	$128,000
Annual cost (1)	7,200	11,000
Annual benefits	10,000	13,400
Benefit-cost ratio	1.39	1.22
Interest rate	6 5/8	7 5/8

(1) Based on 100-year life of project.

The above cost estimate does not include a value for the approximately 1 acre of land required in connection with the proposed control structure. The land is owned by the State of Minnesota (school trust lands). The State has not made a commitment for land transfer or permit costs but has proposed giving Crow Wing County a permanent easement for the structure.

The State of Minnesota may also require the local sponsors to relocate a public access for canoeists. This access would be cut off from the Mississippi River by the proposed control structure. The State may require the local sponsor to provide a similar access on additional lands that must be acquired.

BENEFITS

Approximately 38 residential units are situated around and near Black Bear and Miller Lakes and about 28 of them are subject to flooding from varying flood levels. A field survey of a representative sampling of flood prone properties was made in 1977 and 1978. Approximately 43 percent of the owners were interviewed concerning actual flood damages that occurred in 1975, and estimates were made of damage that would occur with a repeat of the 1950 flood which was approximately 3 feet higher. These two floods have a frequency of occurrence of 7.7 and 1 percent, respectively.

Observed 1975 flood damages were supplemented with a 26-percent telephone sample survey and damage data developed from standard loss tables used by the St. Paul District. These tables gave slightly higher

loss values than the observed damages. An elevation-damage curve was developed using these two flood events and a zero damage point. The zero damage point is the desirable lake level, elevation 1177, as some of the homes have their foundations only 2 feet above the 1177 level. The elevation-damage curve is shown on plate A-86 and the related frequency-damage curve is shown on plate A-87. Total average annual damages from plate A-87 are $10,000, and this damage would be prevented with construction of the proposed levee.

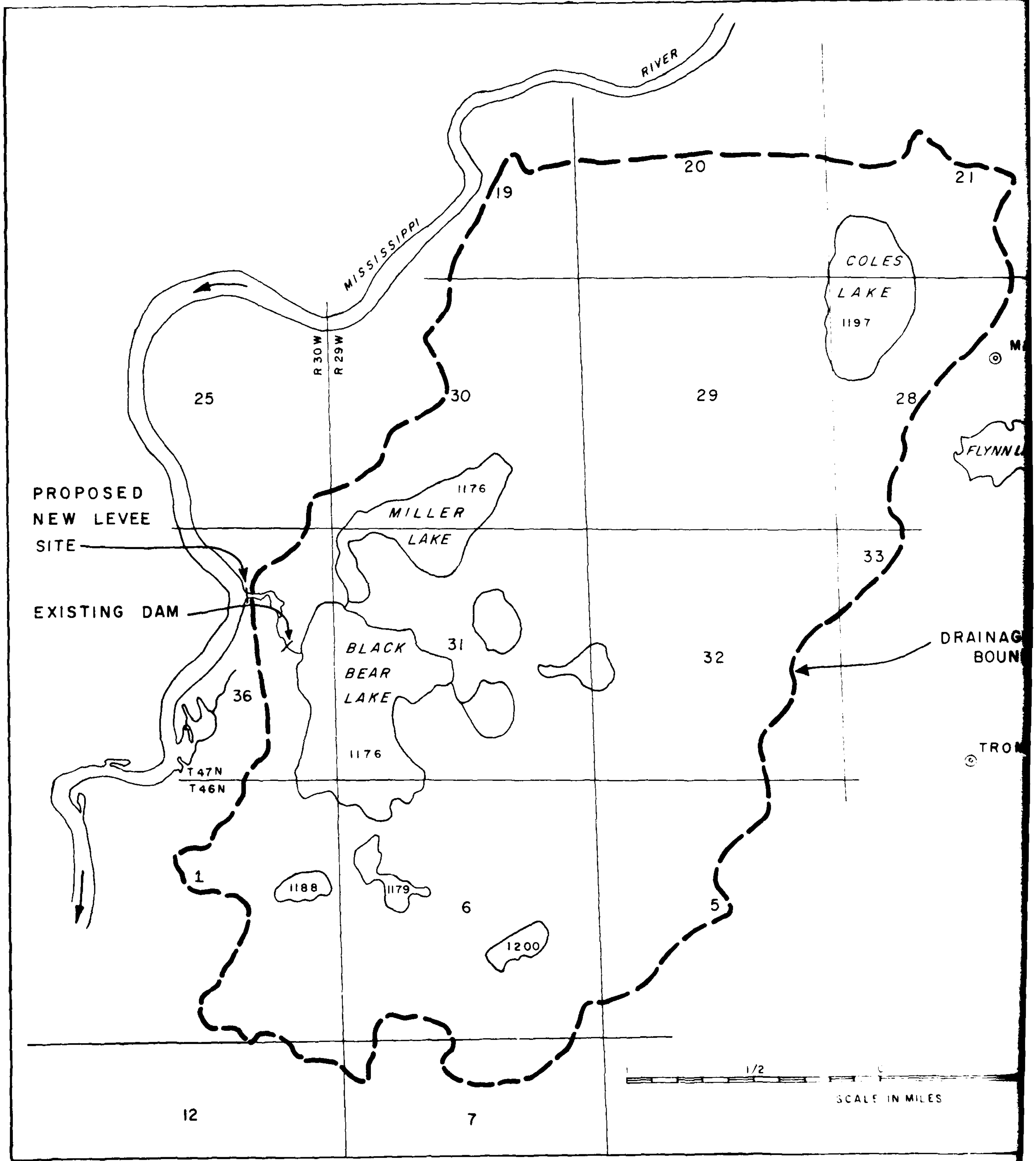
RECOMMENDED ACTION

A nonstructural plan of flood insurance would be economically feasible. This alternative would involve adopting floodplain regulations and restricting further development of the floodplain area around these two lakes. However, the nonstructural plan would not prevent damages but would only compensate for the actual losses.

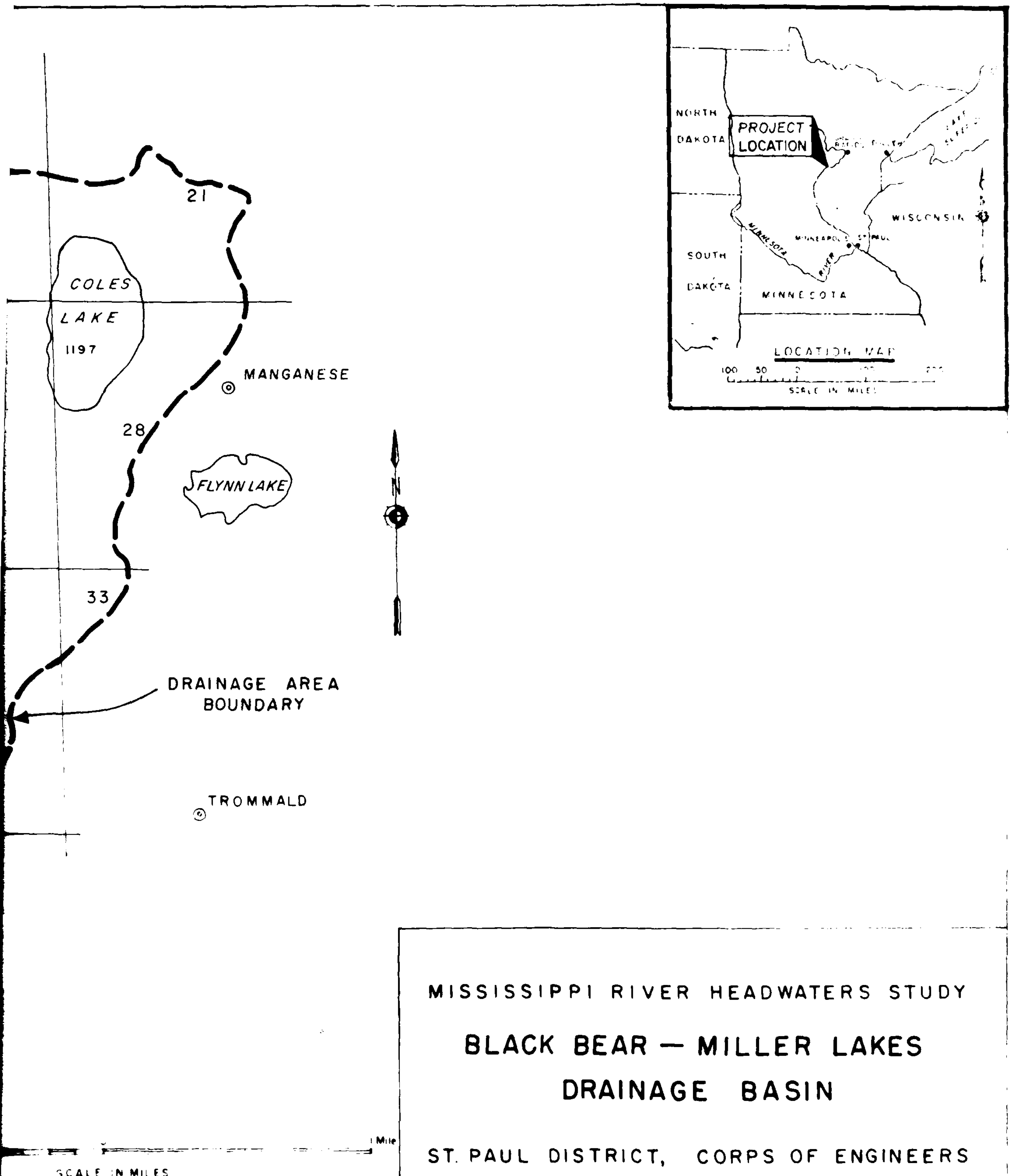
A levee or closure structure that would prevent backup flooding from the Mississippi River would give the best flood protection for this area. The levee is economically feasible. This plan should be evaluated in greater detail under the small projects authority with Crow Wing County as sponsor. The Black Bear-Miller Lakes flood problem will not be evaluated further under the Mississippi Headwaters study authority.

PLATE SUMMARY

Number	Item
A-89	Drainage basin.
A-90	House location sketch map.
A-91	Mississippi River profile.
A-92	Cross section and sketch of proposed dam.
A-93	Elevation versus damages.
A-94	Frequency versus damages.



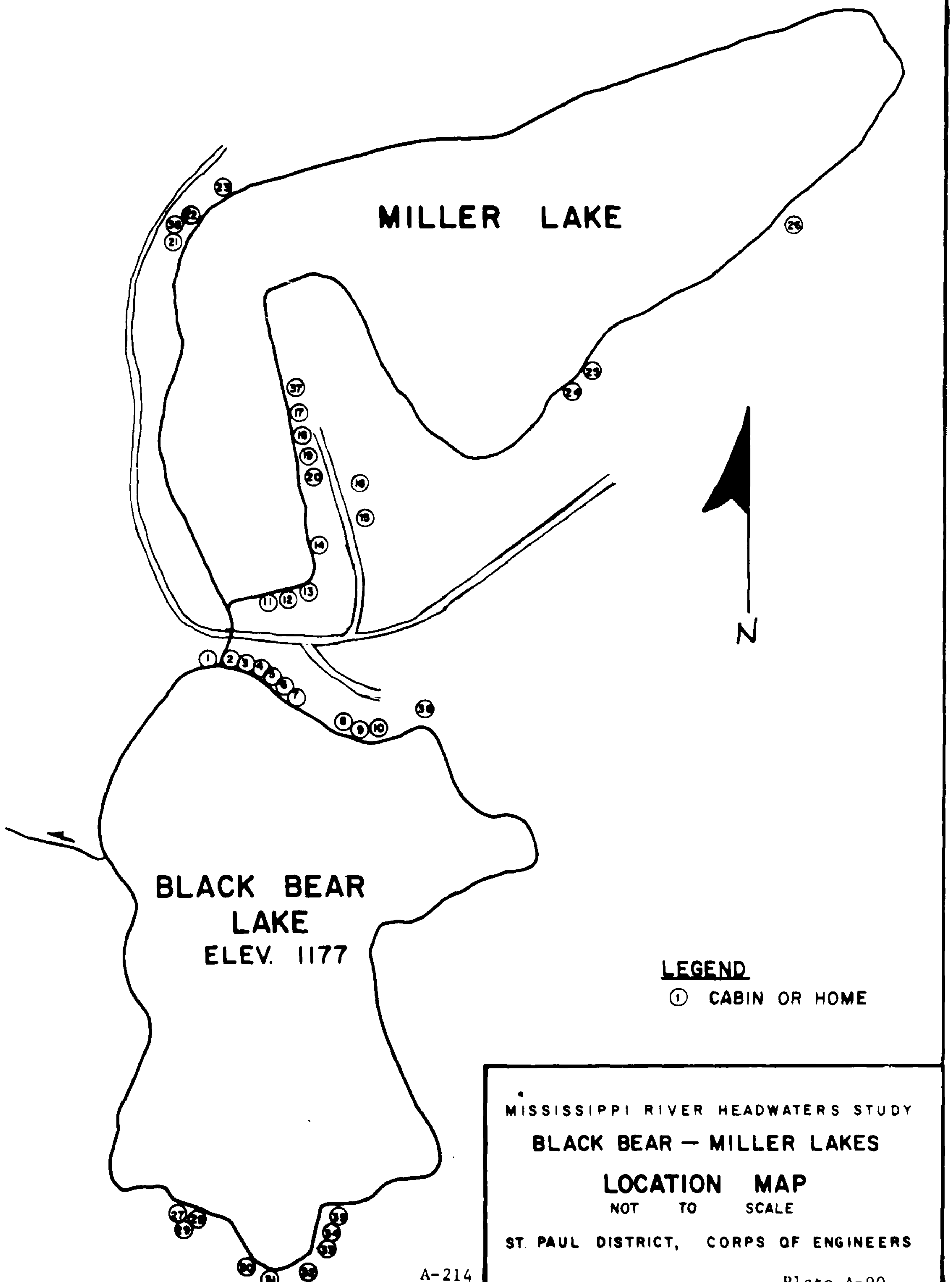
MISSISSIPPI
RIVER
20
21
19
COLES
LAKE
1197
R 30 W
R 29 W
25
30
29
28
FLYNN L
PROPOSED
NEW LEVEE
SITE
1176
MILLER
LAKE
33
EXISTING DAM
BLACK
BEAR
LAKE
31
32
DRAINAG
BOUN
36
1176
TRO
T 47 N
T 46 N
1
1188
1179
6
5
1200
1/2
SCALE IN MILES
12
7



MISSISSIPPI RIVER HEADWATERS STUDY

BLACK BEAR — MILLER LAKES DRAINAGE BASIN

ST. PAUL DISTRICT, CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY

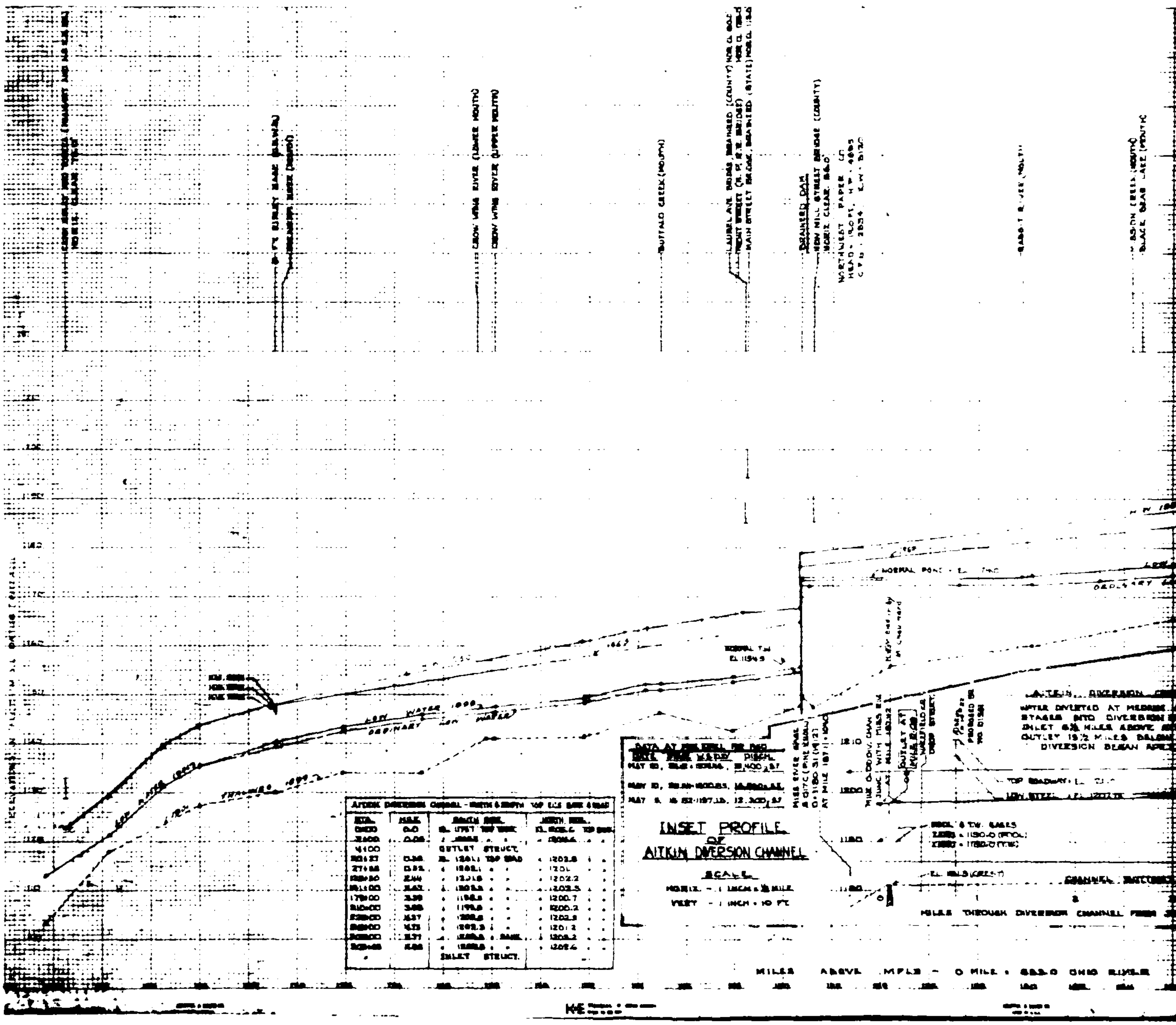
BLACK BEAR — MILLER LAKES

LOCATION MAP

NOT TO SCALE

ST. PAUL DISTRICT, CORPS OF ENGINEERS

Plate A-90


BUFFALO CREEK (MOUTH)
DRUMHEAD DAM
NORMAL POOL
LOW WATER
ORDINARY
INSET PROFILE
OF
AITKIN DIVERSION CHANNEL
SCALE
OUTLET STRUCT.
INLET STRUCT.
MILES THROUGH DIVERSION CHANNEL FROM
MILES ABOVE MPLS

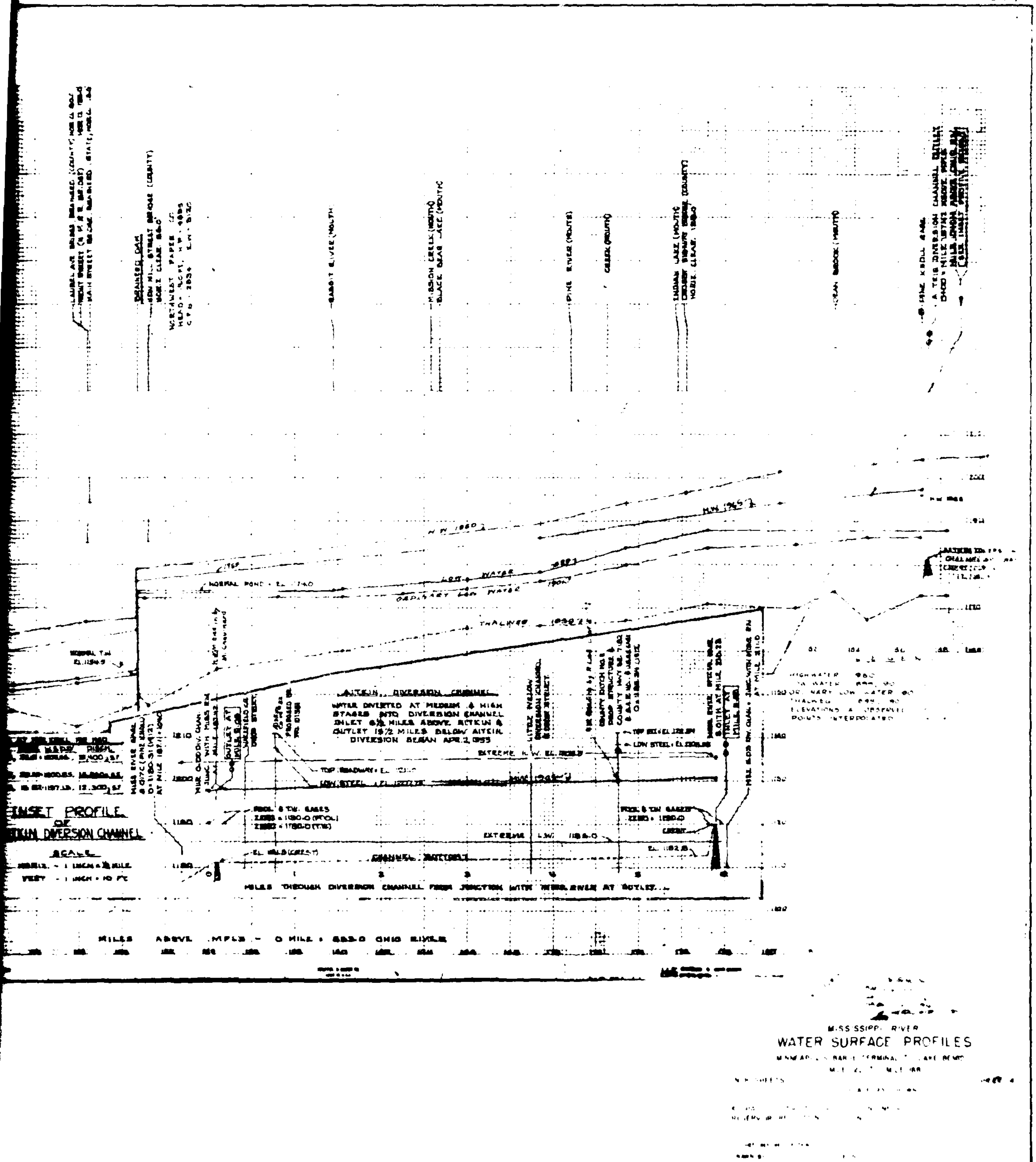
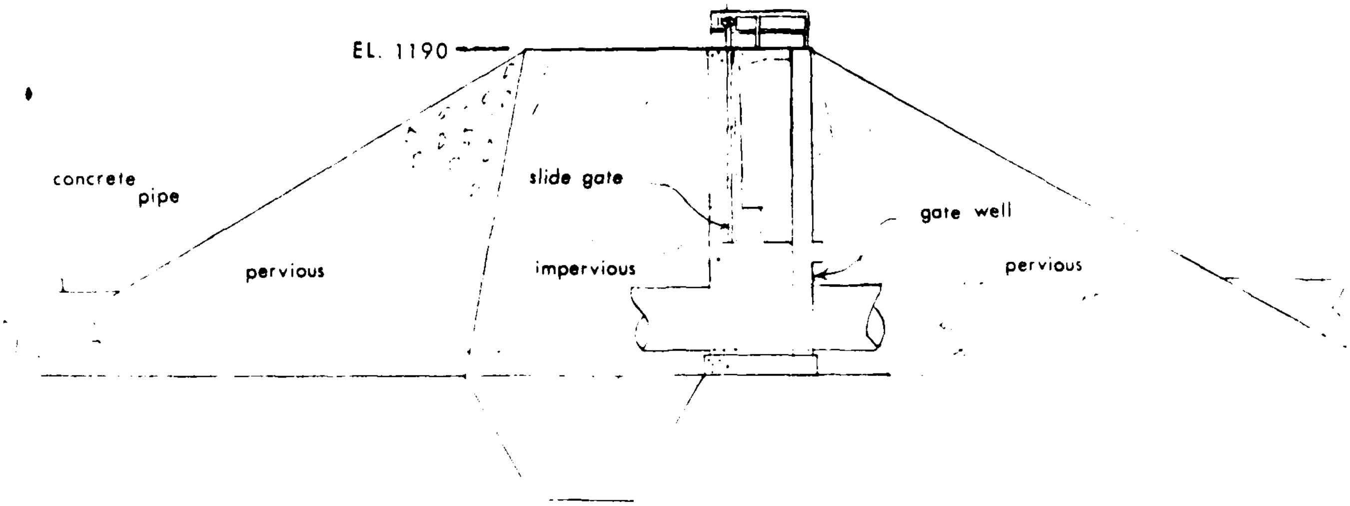
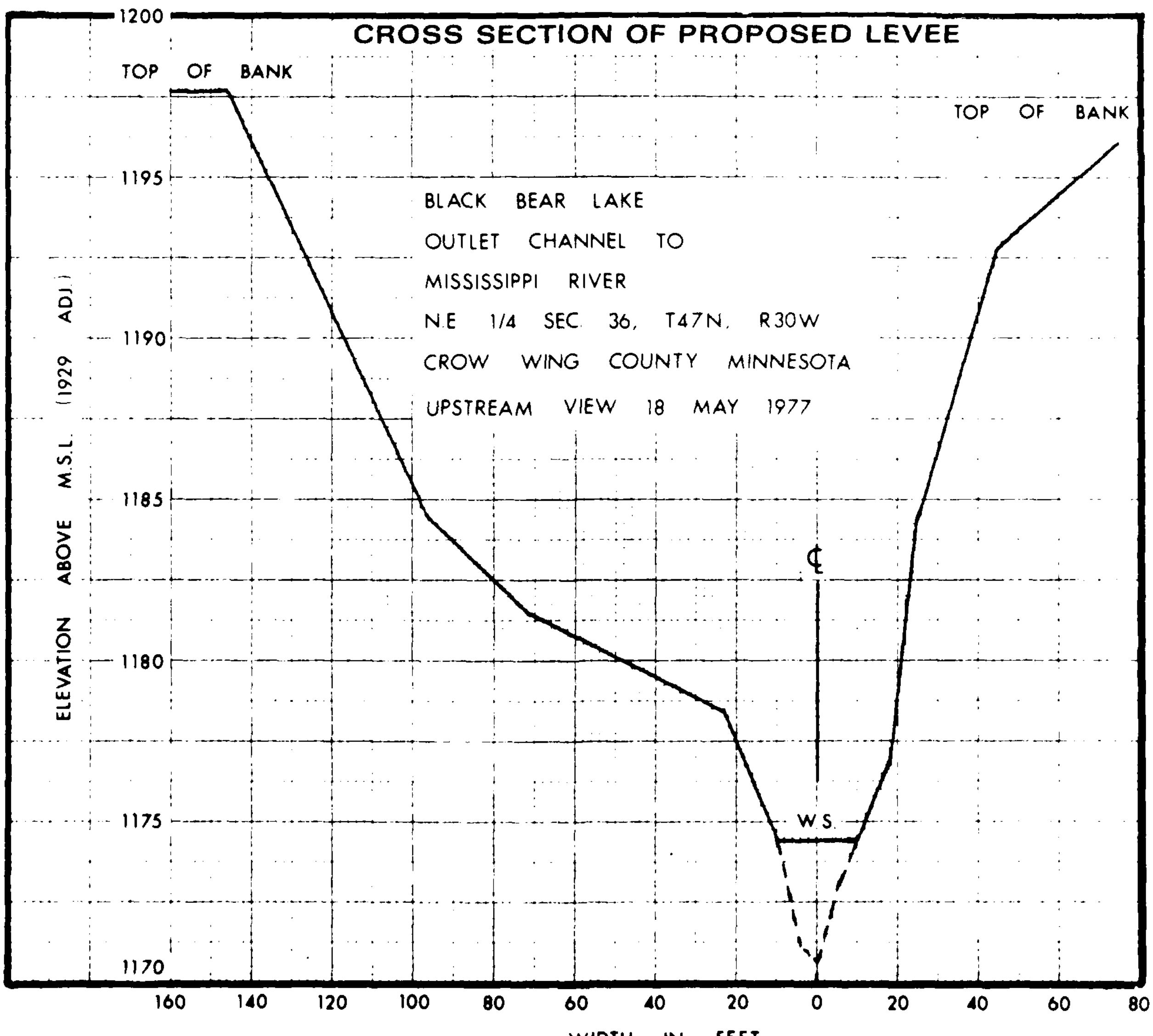
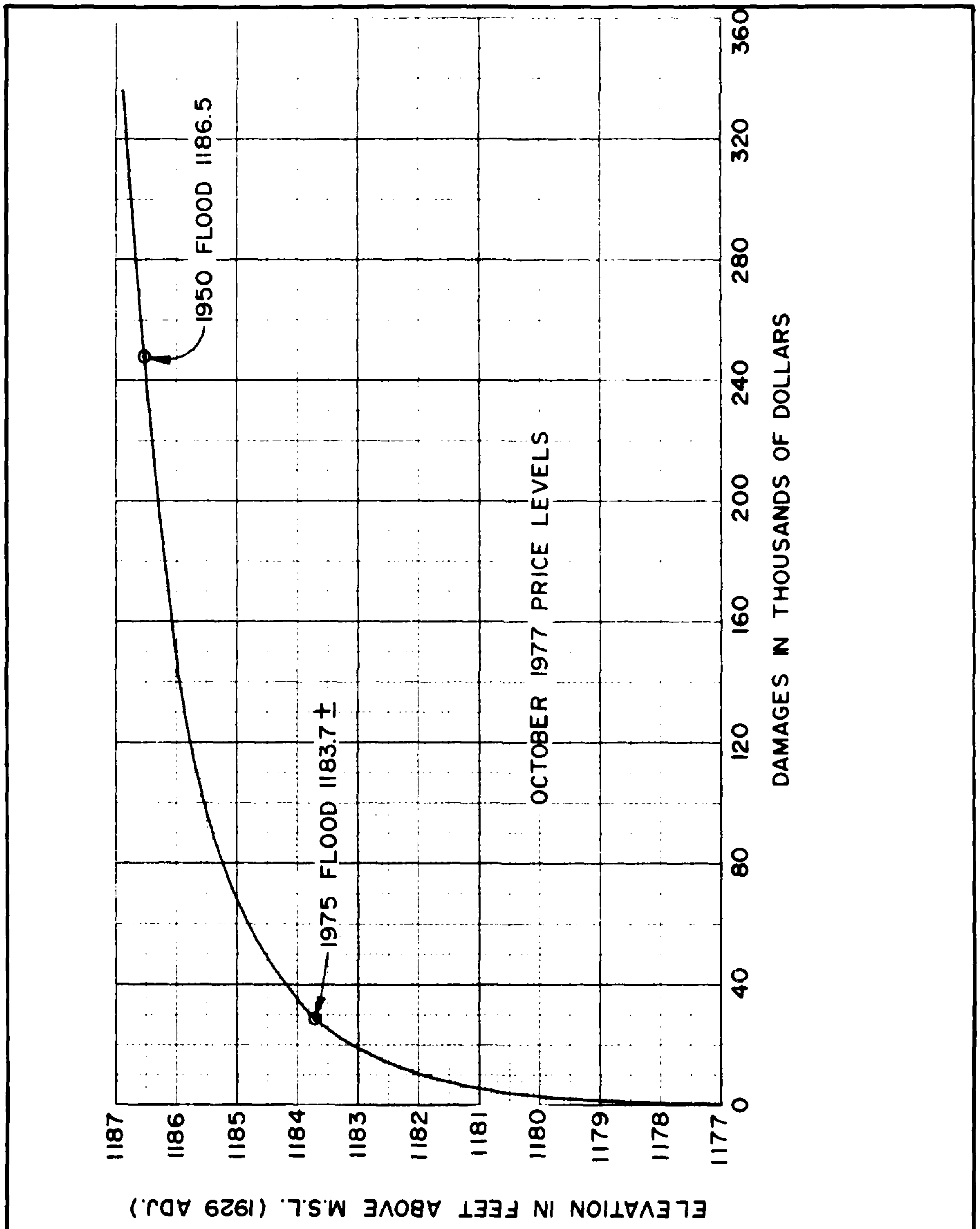

INSET PROFILE OF AITKIN DIVERSION CHANNEL
AITKIN DIVERSION CHANNEL
MILES THROUGH DIVERSION CHANNEL FROM JUNCTION WITH MISS. RIVER AT OUTLET
MILES ABOVE MPLS - 0 MILE = 853.0 OHIO RIVER
THALWEG
LOW WATER
ORDINARY LOW WATER
MISSISSIPPI RIVER
WATER SURFACE PROFILES

PLATE A-81



PROPOSED LEVEE WITH SLIDE GATE, GATE WELL AND CONCRETE PIPE,



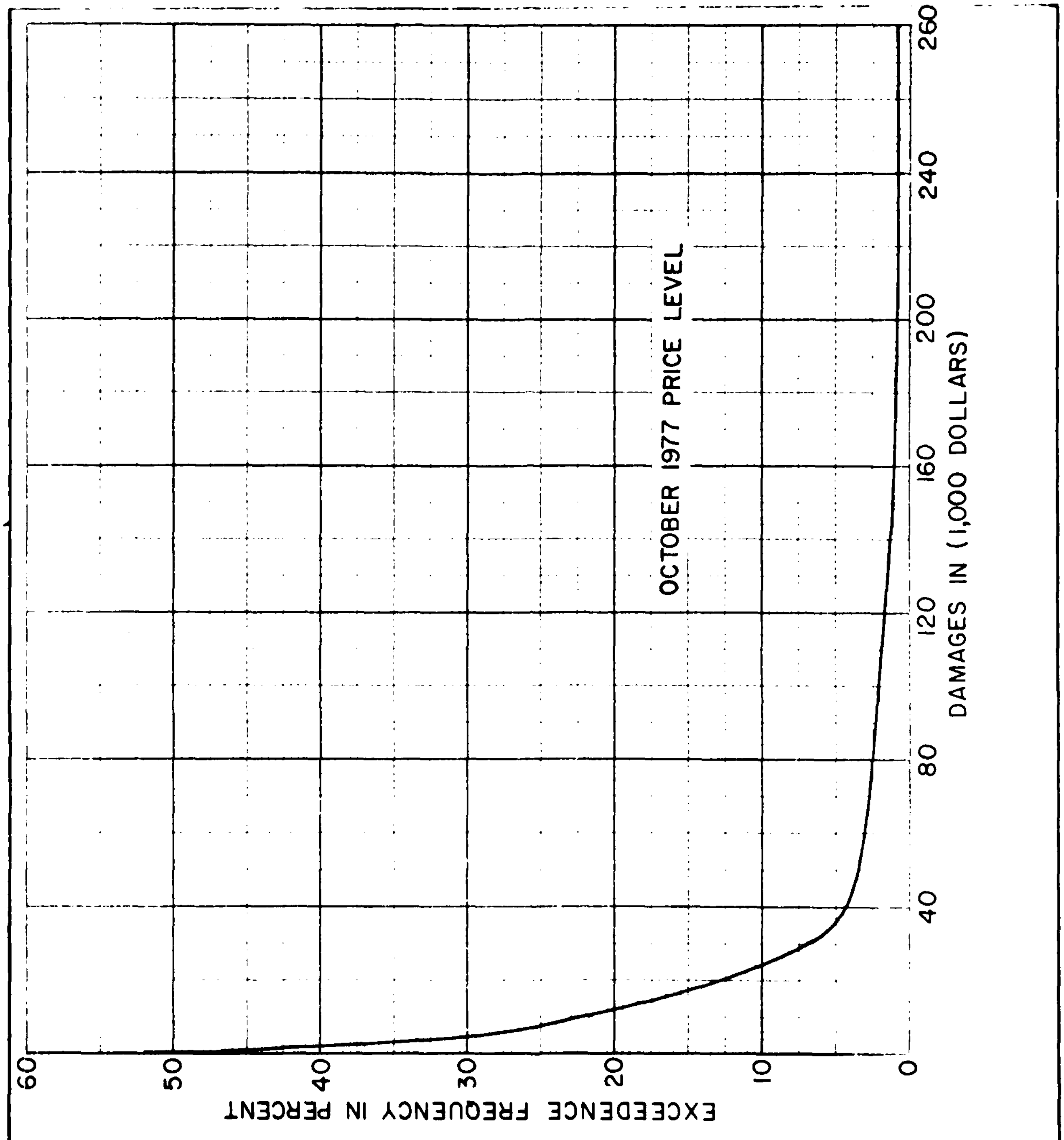


MISSISSIPPI RIVER HEADWATERS STUDY

BLACK BEAR & MILLER LAKES

ELEVATION VS. DAMAGES

ST. PAUL DISTRICT CORPS OF ENGINEERS



MISSISSIPPI RIVER HEADWATERS STUDY

BLACK BEAR & MILLER LAKES
FREQUENCY VS. DAMAGES

ST. PAUL DISTRICT CORPS OF ENGINEERS

PROBLEM 6 - HEADWATERS LAKES PERIMETER DIKES

BACKGROUND

Starting in the late 1800's, perimeter dikes were constructed at several of the headwaters lakes to prevent impounded water from seeking alternative overflow outlets. The need for the dikes apparently was established based on maximum flowage limits and on original topography that may not have been accurate in some areas. The general location of the dikes is shown on plate A-88.

Perimeter dikes exist around the following lakes as defined in June 1972-October 1973 and September 1976 Periodic Inspection Reports by the St. Paul District.

Winnibigoshish Lake	-	4
Leech Lake	-	0
Pokegama Lake	-	4
Sandy Lake	-	4
Pine River Lakes	-	16
Gull Lake	-	0

The dikes have had little, if any, maintenance and are even difficult to identify. In some cases, heavy tree growth has almost obscured them from view. A determination should be made on whether the dikes are needed from a hydrologic standpoint and, if needed, they should be properly evaluated and maintained as impounding structures.

GEOLOGY AND SOILS

Soils data for the 28 perimeter dikes are available from the original drawings for these dikes. General information on soils within the dikes is given on the following table which summarizes data shown on original drawing plates and 1972-1976 engineering inspection reports.

Mississippi River Headwaters Lakes - perimeter dikes summary[1]

Dike No.	Reservoir	Original top elevation: 1929 adjustment	Original top elevation: U.S.E.	Related elevation, 1929 adjustment: Normal pool, highest summer range	Related elevation, 1929 adjustment: Max. pool elevation attained	Related elevation, 1929 adjustment: 100-year elevation, 30-year record	Top width (feet)	Height (feet)	Length (feet)	Side slope [illegible]	Side slope [illegible]	On roadway	Material	General condition	Remarks	Condition of slope (1977)	Slope protection (1977)	Crest and section (1977)
	[illegible]			[illegible]	1224.82	1223.9												
1		[illegible]	[illegible]				20	N/A	[illegible]	1 on 3	1 on 3	Yes	Clay, sandy silt and sand	S	Main access road	S	S	S
2		[illegible]	[illegible]				10	N/A	[illegible]	1 on 3	1 on 3	Yes	[illegible]	S	[illegible]	S	S	S
3		1225.31	[illegible]				10	N/A	[illegible]	1 on 3	1 on 1½	Yes	Silty fine sand	S	Access road to camping area	S	S	S
4		1226.81	1228.5				20	N/A	[illegible]	1 on 3	1 on 3	Yes	Sand, silty, gravelly sand and sandy clay	S	Aitkin Lake Road	S	S	S
	[illegible]			[illegible]	1277.92	1277.9												
1		N/A					30	N/A	[illegible]	N/A	N/A	No	Sandy clay	Dikes appear to be adequate	Located at end of marina	S	S	S
2		N/A	[illegible]				10	N/A	550	N/A	N/A	No	N/A		Roadway nearby could be relied on	S	S	S
3		N/A	[illegible]				20	10-15	[illegible]	N/A	N/A	Yes	N/A		Roadway nearby could be relied on	S	S	S
4		[illegible]	[illegible]				10	1-2	[illegible]	N/A	N/A	No	N/A		Roadway nearby could be relied on	S	S	S
	[illegible]			1299.44	1303.39	1302.9												
1		[illegible]	[illegible]				20	2-3	[illegible]	N/A	N/A	Yes	N/A	Good	Dike No. 1 under Highway 2	S	[illegible]	S
2		[illegible]	[illegible]				10	N/A	[illegible]	N/A	N/A	Yes	Sandy	Adequate	Extensive tree growth on slopes	S	N/A	S
3		[illegible]	[illegible]				10	5-8	[illegible]	1 on 2	1 on 2½	Old trail	N/A	Poor	Extensive tree growth on slopes	S	N/A	S
4		[illegible]	[illegible]				10	5	450	N/A	N/A	No	N/A	Poor	No access to Dike No. 4	S	N/A	S
	[illegible] River			[illegible]	1234.56	1232.8												
1		[illegible]	[illegible]				45	[illegible]	[illegible]	N/A	N/A	Yes	[illegible]	In general, the dikes appear to be substantial, having adequate width, heighth and side slopes.	16-foot blacktop road, trees on slope	X	S	S
2		[illegible]	[illegible]				50	[illegible]	[illegible]	[illegible]	[illegible]	No	[illegible]		[illegible] and brush on slopes	X	S	S
3		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	[illegible]	No	[illegible]		Gravel trail on top, trees on slope	X	S	S
4		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	N/A	No	[illegible]		Dike is not on road	X	S	[illegible]
5		[illegible]	[illegible]				50	[illegible]	[illegible]	[illegible]	N/A	Yes	[illegible]		24-foot blacktop highway, Co. Rd. 3	X	S	
6		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	N/A	Yes	Clayey-sand		24-foot blacktop highway, Co. Rd. 3	X	S	
7		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	N/A	Yes	Clayey-sand		24-foot blacktop highway, Co. Rd. 3	X	S	
8		[illegible]	[illegible]				50	[illegible]	[illegible]	[illegible]	N/A	Yes	Clayey-sand		24-foot blacktop highway, Co. Rd. 3	X	S	
9		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	N/A	Yes	Clayey-sand		24-foot blacktop highway, Co. Rd. 3	X	S	[illegible]
10		[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	N/A	N/A	No	Clayey-sand base fdn.		[illegible]-foot dirt trail on dike, trees on slope	X	S	S
11		[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	N/A	Yes	Sandy clay		[illegible]-foot blacktop township road	X	S	[illegible]
12		[illegible]	[illegible]				25	[illegible]	[illegible]	[illegible]	N/A	No	Sandy clay		Trail on top, trees on slope	X	[illegible]	[illegible]
13		[illegible]	[illegible]				50	[illegible]	[illegible]	N/A	N/A	Yes	Sandy clay		18-foot blacktop road on top	X	[illegible]	[illegible]
14		[illegible]	[illegible]				50	[illegible]	[illegible]	[illegible]	N/A	Yes	Sandy clay		18-foot blacktop road, trees on slopes	X	S	[illegible]
15		[illegible]	[illegible]				50	[illegible]	[illegible]	[illegible]	[illegible]	Yes	Sandy clay		18-foot blacktop road, trees on slopes	X	S	
16		[illegible]	[illegible]				20	[illegible]	[illegible]	[illegible]	1 on 5	No	Gravelly-clayey sandy		Trail on top	X	S	S

(1) KEY:
[illegible] repair and or maintenance needed.
[illegible]

A list of the dikes for which detailed soil borings are currently available is shown in the following table.

Headwaters Lakes dikes - soil borings

Location	Dike number	Number of borings
Perimeter dikes		
Winnibigoshish Lake	3	1
Winnibigoshish Lake	4	1
Sandy Lake	2	7
Sandy Lake	3	1
Pine River Lake (Whitefish Chain of Lakes)	14	1
Main dam		
Winnibigoshish Lake		(3)
Leech Lake		(2)
Pokegama Lake (1)		-
Sandy Lake		(2)
Pine River Lake		(2)
Gull Lake		(3)

(1) Dam built on bedrock.
(2) Boring data are available.
(3) Available data are limited to tabular information on borings included in several Chief of Engineers Reports (1867 to date).

A sample of the boring data available for the perimeter dikes is shown on plate A-89. This plate shows the seven borings available on perimeter dike No. 2 at Sandy Lake. Generally, the available boring data are fragmentary and not a type that would be used for design purposes.

DIKE DESCRIPTIONS

At the start of the current study, specific information concerning location and size of the 28 perimeter dikes was limited. Only a few of the original plates showing proposed construction of the dikes were found. The 28 perimeter dikes were involved in a periodic inspection in 1972 and 1973, but not all dikes could be located in the field. The 28 dikes were located in the field in 1977 as part of the current study, and preliminary field surveys were made in 1978.

The locations of individual dikes are shown on plates A-90 through A-93. Two typical dike profile and cross section sheets for dike Nos. 13 and 14 of the Pine River Lakes area are shown on plates A-94 and A-95.

The 1978 field surveys established the following information for each of the 28 perimeter dikes:

a. Center line profiles of dikes (high ground to high ground).

b. At least one section at maximum fill height and other sections as required.

c. Location of dikes in plan by field tying the profile to two or more temporary points.

The profile and sections were used to make preliminary determinations on the need for the dikes, recommendations for repair and maintenance, and cost estimates for repair and maintenance and to make recommendations regarding acquisition or disposal of property involving the dikes.

A brief summary of the 28 preliminary dikes follows.

Winnibigoshish Lake Perimeter Dikes

Dike No. 1 - Only dike No. 1 is part of a road system in the Winnibigoshish Lake area. This dike is short and low, with a maximum height of 2 or 3 feet, and is probably buried under State Highway No. 2. State Highway 2 is a formidable barrier and thus this dike is not needed. The dike could not be found or specifically located in the field.

Dike No. 2. - Dike 2 consists of six separate segments separated by sand knolls. Resort owners have borrowed considerable fill material from the sand knolls between the short sections of dike No. 2, obliterating any signs of original construction. A large amount of fill has been placed over the main dike segment, completely burying that portion of the dike. Dike No. 2 could easily be protected from overtopping in an emergency, as good access roads are available.

Dike No. 3. - The dike is in two sections, is not maintained, and has considerable tree growth. The east section has an 8-foot maximum height, 15-foot top width, and 1V to 2H and 1V to 3H side slopes. The shorter west section has a similar cross section but a maximum height of 5 feet. The east dike section probably had 4 to 5 feet of water on the lakeward dike side in 1950.

Dike No. 4. - The dike has not been maintained for 25 to 35 years and has considerable tree growth. The cross section is essentially as constructed (10-foot top width, 1V to 2H or 1V to 3H side slopes, and a 5-foot maximum height). The dike probably experienced 1 to 3 feet of water on the lakeward side from the 1950 high water.

Dikes Nos. 2, 3, and 4 prevent escape of water to the south from Lake Winnibigoshish to Leech Lake River via Six Mile Lake. The three dikes are essential during a flood to prevent unauthorized releases from moving downstream.

Pokegama Lake Perimeter Dikes

All dikes except No. 4 are part of an existing road system in the Pokegama Lake area.

Dike No. 1. - Dike No. 1 is located in an old flowage channel between Hale Lake and Pokegama Lake. The dike is at the end of a marina, just downstream of a highway grade. The highway grade is 8 to 10 feet higher than the dike and has 20' bituminous pavement, plus shoulders, and provides a formidable section.

Dike No. 2. - Dike No. 2 prevents Pokegama Lake from entering a small flowage during high water stages. There is a downstream road dike (20-foot top width) at a higher top elevation that would control Pokegama Lake water levels during floods.

Dike No. 3. - Dike No. 3 is another fill closure located between Pokegama and Hale Lakes. The fill is exposed to a long fetch from the northwest at design flood stages. However, a 20-foot wide road is located downstream of the dike that has a top elevation 10 to 15 feet above Pokegama Lake and which would provide a formidable barrier as an alternative to the upstream dike.

Dike No. 4. - Dike No. 4 is a low closure dike that was intended to prevent overflow from Pokegama Lake from Meyers Bay to the Blandin Paper Mill Pool. The Blandin Paper Mill pool is on the Mississippi River downstream of Pokegama Dam. The dike is only 2 feet high maximum with a 10-foot top width and is currently used as a haul road. A 20-foot wide road is located upstream of dike No. 4 with a 15- to 18-inch culvert.

Sandy Lake Perimeter Dikes

All four Sandy Lake dikes are a part of an existing roadway system providing access in the Sandy Lake damsite area.

Dike No. 1 - This dike is the left bank main access road to the campground. It is blacktopped, riprapped, and adequate to hold back water. Continued maintenance is required for the sake of the roadway.

Dike No. 2. - This dike is a tieback to the right embankment of the Sandy Lake outlet structure with 125-foot length and grass cover. Since this dike adjoins the dam, it apparently is needed to prevent water from escaping around the dam. The dike can be readily maintained since it is part of the campgrounds.

Dike No. 3. - Dike No. 3 is a right bank recreation area access road to the camping area with a relatively steep 1 to $1\frac{1}{2}$ backside slope and bituminous surface. This dike is maintained as a road.

Dike No. 4. - This right bank dike, known as Aitkin Lake Road, is 600 feet long. The gravel top is 20 feet wide. The top elevation is 1226.81 and the maximum pool is attained at elevation 1224.82.

Pine River Lake Perimeter Dikes

All of the Pine River Lake perimeter dikes except dikes Nos. 2, 4, and 12 are part of a road system in the Pine River Lake area. Most of the 16 dikes are part of the County Road No. 3 network, with wide top width and high elevations. Dikes are marked with numbered orange fenceposts at each end. In general, the dikes appear to be substantial, having sufficient width, height, and side slopes. Except for dike No. 16, there is no riprap on the dikes. The Pine River Lake perimeter dikes are described in the following table.

Description of Pine River dikes

Number	Length (feet)	Height (feet)	Top width (feet)	Material	Remarks
1	360	15-20	45	Sandy, clayey.	16-foot blacktop road. Trees [illegible] slopes. Road regraded - top elevation unknown.
2	350 plus 100 past end of post	15 side borrow at downstream side height 20	50	Sandy, clayey.	Brush on dike last 100 feet. Grass with scattered small pine on top of remainder. Trees and brush are on both slopes.
3	540	15	50	Clayey sand, sand base foundation.	Gravel trail on top. Grass and trees on slopes. SAR 3 is cut through dike. Road closure approximately 200 feet long [illegible] 5-foot high maximum (3-foot average).
4	390	6 average 10 to toe of borrow	50	Clayey sand, sand base foundation.	Dike is not on road. Actual location [illegible] at Smith's Sandy Shores Resort. [illegible] lake slope are grassed - maintained by resort. Trees on lake slope. Trees and brush on land side. Dike is high [illegible] without closure. SAR 3 grade [illegible] feet below top of dike. No tieback [illegible] - highway grade controls.
5	800	5-6 average 15 maximum	50	Clayey sand, sand base foundation.	24-foot blacktop highway [illegible]. Slopes have trees and brush.
6	1,100	2-3 15 maximum	50	Clayey sand, sand base foundation.	Same as 5.
7	300	10 average 15 maximum	50	Clayey sand, sand base foundation.	Same as 5.
8	400	5-8 15 maximum	50	Clayey sand, sand base foundation.	Same as 5.
9	300	10-12 average 15 maximum	50	Clayey sand, sand base foundation.	Same as 5.
10	200	20 average 20 maximum	50	Clayey sand, sand base foundation.	10-foot dirt trail on dike. Brush and trees on both slopes and top. Dike is adjacent to lakeshore.
11	1,000	10 average 20 maximum	35	Sandy clay.	18-foot blacktop township road on top. Trees on both slopes.
12	100	5 average 10 maximum	20	Sandy clay.	Trail on top. Trees on both slopes.
13	1,000	20 maximum 10 average	50	Sandy clay.	18-foot township road on top. Trees on both slopes. Slopes 1 on 3 upstream and 1 on 4 downstream. Water at both sides of dike.
14	150	20 maximum and average	50	Sandy clay.	18-foot township road on top. Trees on both slopes.
15	150	20 average and maximum	50	Sandy clay.	18-foot township road on top. Trees on both slopes. This dike is designated as dike 16 on all real estate maps and [illegible] office plans. Dike 15 as shown on the plans does not exist.
16	150	15 maximum and average	20	Gravelly sandy clay (rock to 2-inch maximum size).	Slopes 1 on 3 upstream and 1 on [illegible] downstream. Trail on top. Trees at top and on downstream slopes. [illegible] feet thick on upstream slope. [illegible] is same as for 12-foot thickness. Dike is on Clam [illegible] Lake and has no marker [illegible].

NOTE: Dikes are marked with numbered orange fenceposts at each end.

HYDROLOGY AND HYDRAULIC STUDIES

General

A stage-frequency analysis based on the period of record 1936-76 was developed earlier as part of the overall study. The present condition stage-frequency analysis was based on the period 1936-76 because records before 1936 reflected a different plan of operation for the Mississippi River Headwaters Lakes. Stage-frequency conditions for each of the six headwaters lakes were shown previously on plates A-54 through A-60 under problem 2, bank erosion control on six Mississippi River Headwaters Lakes.

Design (standard project flood analysis)

An evaluation of the safety of each perimeter dike was made for this study. Based on the policy discussed in paragraph 6, EC 1110-2-163, the Mississippi River Headwaters Lakes are considered to be closest to standard 2 of the functional design standards for spillways and dams. Paragraph 6c(3) of the EC states that nonoverflow sections of standard 2 dams shall be designed high enough to avoid overtopping during a standard design flood comparable to or more severe than the standard project flood, including appropriate freeboard allowances for wave action and other relevant considerations.

To consider the possibility of a standard project flood occurring after a period of high runoff, a standard project flood series was developed for this study. The year 1950 was selected as the basis for the standard project flood series. The standard project flood routings were initiated when the high spring runoff from the 1950 flood had begun to recede. The peak elevations attained in each lake for the standard project flood routings are the freeboard reference levels that should be used in determining adequate top of dam heights at each location. The freeboard reference levels for Sandy Lake are caused by backwater from the standard project flood on the Mississippi River at the mouth of Sandy River. The freeboard reference levels are:

Lake	Freeboard reference level (1929 datum)
Winnibigoshish	1304.44
Leech	1297.10
Pokegama	1277.97
Sandy	1226.81
Pine River (Cross Lake)	1234.32
Gull	1197.65

Methods for computing the design wave height and height of wave runup on embankments associated with projects designed according to standard 2 are shown in Appendix D of EC 1110-2-163 and the following references:

a. "Wave Runup and Wind Setup on Reservoir Embankments," McCartney, Bruce L., U.S. Army Corps of Engineers, Office of the Chief of Engineers, ETL 1110-2-221, November 1967.

b. "Slope Protection Design for Embankments in Reservoirs," U.S. Army Corps of Engineers, Office of the Chief of Engineers, ETL 1110-2-222, 10 July 1978.

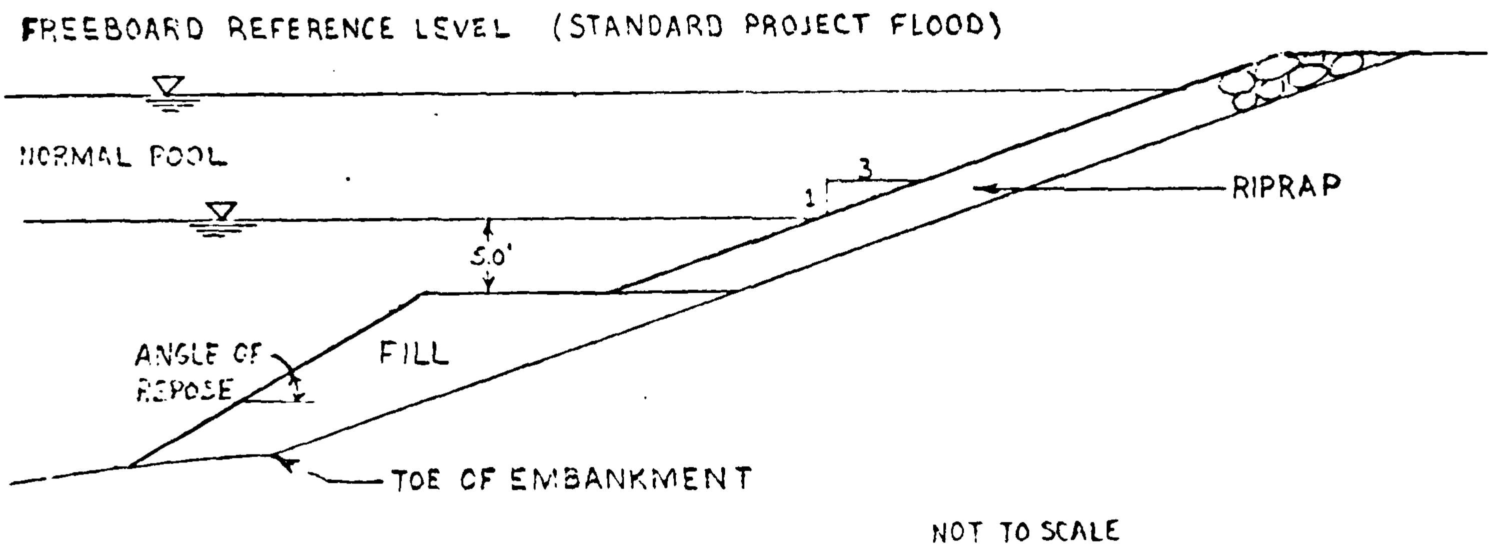
c. "Earth and Rock-Fill Dams, General Design and Construction Considerations," U.S. Army Corps of Engineers, Office of the Chief of Engineers, EM 1110-2-2300, 1 March 1971.

d. "Shore Protection Manual," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia, Volumes I, II, and III, 1977.

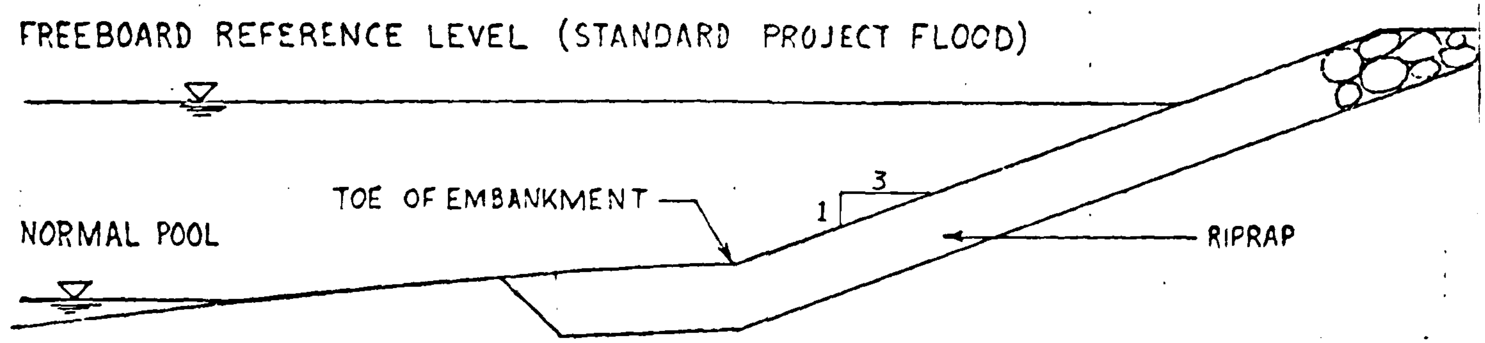
e. "Wind-Wave Propagation Over Vegetated Land," Frederick E. Canfield, Technical Paper No. 77-12, October 1977.

Using the policy discussed in EC 1110-2-163, the required top elevation of the embankment is equal to the height of wave runup for the significant wave and wind setup on the embankment plus the freeboard reference level. (The significant wave height is the average of the one-third highest of a given wave group. The significant wave height will be exceeded by approximately 13 percent of the waves.) If the difference in elevation determined by adding wave runup and wind setup is less than 3 feet, then a minimum of 3 feet of freeboard above the freeboard reference level is recommended.

According to EM 1110-2-2300, upstream slope protection provided for wave erosion is required from the embankment crest elevation to 5 feet below the elevation of the conservation pool. (The elevation of the normal pool is recommended for the Mississippi River Headwaters Lakes.) Dikes located landward of the existing shoreline are protected from the ground line to the required minimum embankment crest elevation. Riprap protection for the dikes considered in this study should be provided to the elevation attained with the height of wave runup and wind setup plus the freeboard reference level. The size of stone and layer thickness of riprap are based on equations presented in ETL 1110-2-222. The following two figures illustrate how riprap would be placed on typical embankments.



TYPICAL SKETCH OF PROTECTION PLACEMENT FOR EMBANKMENTS WHERE NORMAL POOL ELEV. > EMBANKMENT TOE ELEV.



NOT TO SCALE

TYPICAL SKETCH OF PROTECTION PLACEMENT FOR EMBANKMENTS WHERE NORMAL POOL ELEV. < EMBANKMENT TOE ELEV.

Typical lake data for the Mississippi River Headwaters Lakes and resulting embankment characteristics for existing and proposed conditions are shown in the following tables. This information was used to develop the succeeding cost estimates for upgrading the perimeter dikes and is based on 1977 field survey data.

LAKE DATA - Mississippi River Headwaters Perimeter Dikes and Main Embankments

Item	Winnibigoshish		Leech	Pokegama		Sandy		Pine		Gull
1. RESERVOIR LEVEL										
a. Normal pool elevation, feet msl	1299		1296	1273		1216		1230		1294
b. Maximum observed lake elevation, feet msl	1303.17		1297.07	1277.89		1226.82		1231.98		1195.[illegible]
c. 100-year flood elevation, feet msl	1302.90		1297.0	1277.9		[illegible]		1232.6		119[illegible].4
2. FREEBOARD REFERENCE LEVEL (Standard Project Flood)										
a. Reservoir elevation, feet	1304.44		1297.10	1277.97		1226.81		1234.32		1197.[illegible]
3. FETCH DISTANCE	Minimum	Maximum		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
a. Effective fetch (Fe) for wave computations, miles	9.5	11.2	4.0	0.2	2.6	0.6	2.2	0.2	2.4	0.2
b. Fetch used in wind tide computations (assumed as 2Fe), miles	19.0	22.4	8.0	0.4	5.2	1.1	4.4	0.4	4.8	0.4
4. OVERLAND DESIGN WIND										
a. Durations, hours	1.43	1.62	0.75	0.20	0.53	0.16	0.48	0.08	0.52	0.10
b. Average overland velocity, mph	40		40	40		40		40		40
5. WIND TIDE HEIGHT										
a. Water depth assumed in computations, feet	20	38	8.7	10	45	10	27	10	[illegible]	5
b. Wind tide height above FRL, feet	1.0	1.7	1.7	0.1	0.3	0.3	0.5	0.1	0.5	0.1
6. WAVE CHARACTERISTICS										
a. Wave height (H_s) with no reduction for breaking waves or vegetation effects, feet msl	4.3	5.9	3.0	1.3	5.0	2.0	3.5	0	3.4	1.5
b. Design wave height (H_s)[1] for perimeter dikes and main embankments, feet msl	2.0	4.3	2.1	1.3	2.3	1.0	2.0	0	3.4	0.8
c. Maximum wave height (1.67 H_s) for perimeter dikes and main embankments, feet msl	3.3	7.2	3.5	2.2	3.8	1.7	3.3	0	5.7	1.[illegible]
7. MAXIMUM WAVE RUNUP ON EMBANKMENT SECTION WITH RIPRAP										
a. Height of H_s runup above FRL, feet	3.2	5.1	3.5	1.4	2.9	1.0	2.1	0	1.6	0.8
b. Maximum elevation of H_s runup (items 2a + 5b + 7a)	1308.6	1311.2	1300.3	1279.5	1280.9	1228.1	122[illegible].3	1235.2	1236.2	1198.6
9. REQUIRED TOP ELEVATION OF EMBANKMENT SECTION WITH RIPRAP										
a. Minimum freeboard above FRL (item 7a is less)	3.0	3.0	0	3.0		3.0		3.0		3.0
b. Required freeboard[2] above FRL (items 5b + 7a), feet msl	4.2	6.8	3.2	3.0		3.0		3.0		3.0
c. Required top of embankment (items 2a + 9b), feet msl	1308.6	1311.2	1300.3	1281.0	1281.0	1229.8	1229.8	1237.3	123[illegible].3	1200.7

[1] Design wave height includes the effects of waves breaking in shallow water and wave decay in a vegetated segment, where applicable.
[2] A minimum of 3.0 feet of freeboard is required.

Mississippi River Headwaters Lakes - Perimeter Dikes Existing Embankment Characteristics

Lake	Dike No.	Freeboard Reference Level (feet)	Max. Elev. Attained with Design Wave (feet)	Existing Controlling Dike Elevation (feet)	Existing Dike Overtopped	Existing Slope Protection on Lake Side of Embankment	Existing Dike Side Slope: Lake	Existing Dike Side Slope: Land	Existing Dike Top Width (feet)
SANDY									
(Main Embankment)	1	1226.81	1230.1	1227.8	yes (2.3 ft.)	Brush & Riprap	1 on 2.5	1 on 2	[illegible]
	2	"	1229.5	1225.1	yes (4.4 ft.)	Grass	1 on 3	1 on 3	[illegible]
	3	"	1229.6	1225.7	yes (3.9 ft.)	Riprap	1 on 3	1 on 3	[illegible]
	4	"	1228.5	1227.2	yes (1.3 ft.)	Brush	1 on 3	1 on 2	[illegible]
POKEGAMA									
(Main Embankment)	-	1277.72	1279.8	1279.4	yes (0.4 ft.)	Riprap	1 on 2.3	1 on 3	[illegible]
	1	"	1282.1	1283.1	no	Brush	1 on 3	1 on 2	[illegible]
	2	"	1282.1	1279.9	yes (2.2 ft.)	Trees	1 on 4	1 on 3	[illegible]
	3	"	1282.1	1284.0	no	Grass	1 on 2	1 on 3	[illegible]
	4	"	----	1279.0	yes[1]	Trees	1 on 3	1 on 2	[illegible]
(Roadway near Dike No.4)	-	"	1280.7	1279.2	yes (1.5 ft.)	Trees	1 on 2	1 on 2	[illegible]
WINNIBIGOSHISH									
(Main Embankment)	-	1304.44	1315.9	1309.9	yes (6.0 ft.)	Riprap	1 on 2	1 on 2	[illegible]
	1	"	----[2]	----	----	----	----	----	--
	2	"	1310.4	1303.2	yes (7.2 ft.)	Trees	1 on 2	[illegible]	[illegible]
	3	"	1310.4	1305.9	yes (4.5 ft.)	Trees	1 on 2	1 on 1.5	[illegible]
	4	"	1310.4	1306.0	yes (4.4 ft.)	Trees	1 on 2	1 on 3	
PINE RIVER (CROSS LAKE)									
(Main Embankment)	-	1234.3	1233.1	1237.5	yes ([illegible] ft.)	Riprap	1 on 3	1 on 2	[illegible]
	1	"	1236.5	1243.7	no	Brush	1 on 5	[illegible]	[illegible]
	2	"	----	1242.0	no	Trees	1 on 5	1 on 4	[illegible]
	3	"	1235.8	1240.9	no	Trees	1 on 8	1 on 3	[illegible]
	4	"	----	1239.6	no	Grass	1 on 14	1 on 6	[illegible]
	5	"	1238.1	1240.0	no	Grass	1 on 4	1 on 4	[illegible]
	6	"	1238.1	1241.1	no	Grass	1 on 4	1 on 4	[illegible]
	7	"	1238.1	1242.0	no	Grass	1 on 3	1 on 4	[illegible]
	8	"	1238.1	1243.0	no	Grass	1 on 4	1 on 5	[illegible]
	9	"	1236.2	1242.3	no	Trees	1 on 3	1 on 4	[illegible]
	10	"	1236.2	1242.6	no	Brush	1 on 5	1 on 4	[illegible]
	11	"	1236.2	1242.6	no	Trees	1 on 4	[illegible]	[illegible]
	12	"	----	1243.0	no	Trees	1 on 4	[illegible]	[illegible]
	13	"	1236.2	1243.5	no	Trees	1 on 3	[illegible]	[illegible]
	14	"	1236.2	1241.5	no	Trees	1 on 8	[illegible]	[illegible]
	15	"	1236.0	1243.2	no	Trees	[illegible]	[illegible]	[illegible]
	16	"	1233.3	1240.9	no	Riprap	1 on 4	[illegible]	[illegible]
GULL									
(Main Embankment)	-	1197.7	1198.6	1198.1	yes (0.5 ft.)	Grass	1 on 4	[illegible]	[illegible]
LEECH									
(Main Embankment)	-	1297.1	1303.4	1313.4	no	Riprap	1 on 2	1 on 3	[illegible]

[1] Freeboard is less than 3 feet.

[2] Location and other pertinent data for this dike is unknown.

Mississippi River Headwaters Lakes – Perimeter Dikes Embankment Characteristics
for Freeboard and Erosion Protection Requirements in EC 1110-2-163, EM 1110-2-221, and ETL 1110-2-222

Lake	Dike No.	Freeboard Reference Level (feet)	Max. Elev. Attained with Design Wave on Standard Slope (feet)	Minimum Freeboard Required (feet)	Required Minimum Top of Dike Elevation (feet)	Required Slope Protection for No Erosion	Recommended Typical Bottom of Riprap Elevation (feet – 1929 Adj.)	Recommended Top of Riprap Elevation (feet – 1929 Adj.)	Specific Gravity of Riprap Used in Computations	Recommended Riprap Layer Thickness (inches)
SANDY										
(Main Embankment)	1	1226.81	1229.3	3.0	1229.81	Riprap	1221.8	1229.8	2.65	12
	2	"	1218.9	3.0	1229.81	Riprap	1219.2	1229.3	2.65	12
	3	"	1219.0	3.0	1229.81	Riprap	1216.8	1229.8	2.65	12
	4	"	1228.1	3.0	1229.81	Riprap	1221.7	1229.8	2.65	12
POKEGAMA										
(Main Embankment)	-	1277.92	1279.5	3.0	1280.9	Riprap	1264.0	1280.9	2.65	12
	1	"	1280.9	3.0	1280.9	Riprap	1275.5	1280.9	2.65	12
	2	"	1280.9	3.0	1280.9	Riprap	1274.4	1280.9	2.65	12
	3	"	1280.9	3.0	1280.9	Riprap	1273.1	1280.9	2.65	12
	4	"	----	3.0	1280.9	Grass[1]	----	----	--	--
(Roadway near Dike No. 4)	-	"	1279.9	3.0	1280.9	Riprap	1278.2	1280.9	2.65	12
WINNIBIGOSHISH										
(Main Embankment)	-	1304.44	1311.2	3.0	1311.2	Riprap	1296.8	1311.2	2.65	2?
	1	"	----	3.0	----	----	----	----	--	--
	2	"	1308.6	3.0	1308.6	Riprap	1299.5	1308.6	2.65	12
	3	"	1308.6	3.0	1308.6	Riprap	1298.3	1308.6	2.65	12
	4	"	1308.6	3.0	1308.6	Riprap	1301.8	1308.6	2.65	12
PINE RIVER (CROSS LAKE)										
(Main Embankment)	-	1234.3	1236.0	3.0	1237.3	Riprap	1232.5	1237.3	2.65	18
	1	"	1236.0	3.0	1237.3	Riprap	1229.0	1237.3	2.65	12
	2	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	3	"	1235.5	3.0	1237.3	Riprap	1231.2	1237.3	2.65	12
	4	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	5	"	1236.2	3.0	1237.3	Riprap	1231.9	1237.3	2.65	12
	6	"	1236.2	3.0	1237.3	Riprap	1230.2	1237.3	2.65	12
	7	"	1236.2	3.0	1237.3	Riprap	1232.0	1237.3	2.65	12
	8	"	1236.2	3.0	1237.3	Riprap	1232.0	1237.3	2.65	12
	9	"	1235.8	3.0	1237.3	Riprap	1233.0	1237.3	2.65	12
	10	"	1235.3	3.0	1237.3	Riprap	1233.5	1237.3	2.65	12
	11	"	1235.8	3.0	1237.3	Riprap	1229.5	1237.3	2.65	12
	12	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	13	"	[illegible]	3.0	1237.3	Riprap	1224.4	1237.3	2.65	12
	14	"	1235.5	3.0	1237.3	Riprap	1226.4	1237.3	2.65	12
	15	"	1233.2	3.0	1237.3	Riprap	1226.3	1237.3	2.65	12
	16	"	1235.5	3.0	1237.3	Riprap	1225.4	1237.3	2.65	12
GULL										
(Main Embankment)	-	1194.7	1196.?	3.0	[illegible]	Riprap	1188.6	1200.2	2.65	12
[illegible]										
[illegible]	[illegible]	1??	[illegible]	3.0	[illegible]	[illegible]	1188.5	1200.3	2.65	12

[1] [illegible]

Mississippi River Headwaters Lakes – Perimeter Dikes Embankment Characteristics
for Freeboard and Erosion Protection Requirements in EC 1110-2-163, EM 1110-2-221, and ETL 1110-2-222 – continued

Lake	Dike No.	Recommended Median Rock Size (pounds)	Recommended Maximum Rock Size (pounds)	Recommended Minimum Rock Size (pounds)	Recommended Dike Side Slope: Lake	Recommended Dike Side Slope: Land	Minimum Top Width Required* (feet)	Comments
SANDY								
(Main Embankment)	1	23	92	3	1 on 3	1 on 5	10	
	2	22	88	3	1 on 3	1 on 5	10	
	3	11	44	2	1 on 3	1 on 5	10	
	4	3	12	1	1 on 3	1 on 5	10	
POKEGAMA								
(Main Embankment)	–	8	32	1	1 on 3	1 on 5	10	
	1	30	120	4	1 on 3	1 on 5	10	
	2	30	120	4	1 on 3	1 on 5	10	Roadway nearby could serve as dike. Elevation of roadway is 1282.5
	3	30	120	4	1 on 3	1 on 5	10	Dike is under 24' bituminous road. Elevation 1284.0.
	4	—	--	--	1 on 3	1 on 5	10	Roadway nearby could serve as dike. Elevation of roadway is 1279.2.
(Roadway near Dike No. 4)	–	34	136	5	1 on 3	1 on 5	10	
WINNIBIGOSHISH								
(Main Embankment)	–	300	1200	40	1 on 3	1 on 5	10	
	1	--	--	--	----	----	--	Dike under State Highway No. 2
	2	22	90	3	1 on 3	1 on 5	10	
	3	22	90	3	1 on 3	1 on 5	10	
	4	22	90	3	1 on 3	1 on 5	10	
PINE RIVER (CROSS LAKE)								
(Main Embankment)	–	[illegible]	450	[illegible]	1 on 5	[illegible]	10	
	1	[illegible]	46	[illegible]	1 on 5	1 on 5	10	
	2	—	--	--	1 on 5	[illegible]	[illegible]	
	3	[illegible]	[illegible]	2	1 on 8	1 on 5	10	
	4	—	--	[illegible]	1 on 4	[illegible]	10	
	5	[illegible]	[illegible]	1	1 on 4	1 on 5	10	
	6	[illegible]	[illegible]	1	1 on 4	[illegible]	10	
	7	[illegible]	[illegible]	[illegible]	1 on 3	1 on 5	10	
	8	[illegible]	[illegible]	[illegible]	1 on 4	[illegible]	10	
	[illegible]	[illegible]	[illegible]	3	1 on 3	1 on 5	10	
	[illegible]	[illegible]	30	[illegible]	1 on 5	[illegible]	10	Dike system has a low point on swale at elevation 1237.9.
	[illegible]	[illegible]	[illegible]	[illegible]	1 on 4	1 on 5	10	Dike system has a low point at elevation [illegible].5 on [illegible]-foot bituminous road.
	[illegible]	--	--	--	1 on 4	[illegible]	10	Dike system has a low point at elevation [illegible].5 east of West Shore Drive.
	13	[illegible]	[illegible]	[illegible]	1 on 3	[illegible]	10	
	[illegible]	[illegible]	[illegible]	[illegible]	1 on 5	[illegible]	10	
	[illegible]	[illegible]	1	1	1 on 5	1 on 5	10	
	[illegible]	[illegible]	[illegible]	[illegible]	1 on 4	1 on 5	10	
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 on 4	1 on 5	10	
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	

* [illegible] is greater than 10 feet [illegible] the larger existing top width [illegible]

The previous tables show that most of the perimeter dikes would require riprapping to comply with the specified design criteria. The perimeter dikes that would also require additional freeboard are as follows:

Sandy Lake:	Dikes 1, 2, 3, and 4.
Pokegama Lake:	Dikes 2 and 4.
Winnibigoshish Lake:	Dikes 2, 3, and 4.

The required design height for the perimeter dikes at each area is shown below for estimating purposes.

Lake	Design height
Winnibigoshish	1308.6
Pokegama	1280.9
Sandy	1229.8
Pine River	1237.3

All perimeter dikes, including those to be upgraded, would be grubbed and cleared. The upgraded dikes would be stripped of vegetation and organic material and raised to the required design level with compacted fill. Side slopes would generally be 1V on 5H on the downstream side and 1V on 3H on the upstream side. A minimum top width of 10 feet was used for raised dike sections except where the previous dike carried an improved road surface. In these instances, the top width of the dikes was rebuilt to the original road width.

The Sandy Lake perimeter dikes raised to elevation 1229.8 would not be effective without also raising or replacing the existing Sandy Lake control structure. The present top of concrete piers and top of roadway across the concrete control structure are at elevation 1221.3 and 1223.5, respectively.

A new control structure would probably be needed in lieu of a raise of the existing structure. The existing structure would be removed and filled in and a new control would be built at another location. A detailed cost estimate is not available for this work, but a tentative value was developed from a comparison of actual structural costs at other locations in the St. Paul District, indexed to October 1977 price levels. The tentative cost estimate for this work as shown in subsequent tables is estimated at $8 million. This cost could be considerably higher if the downstream highway bridge would require modification.

COST ESTIMATE

Preliminary construction cost estimates for each of the four headwaters lakes areas with perimeter dikes are presented in the following tables. All costs are in October 1977 price levels. The interest rate is 7 5/8 percent with a 100-year project life. A summary table for the four areas precedes a more detailed cost summary for each area.

Upgrade perimeter dikes(1) - summary of structural plan cost data

Lake area	First cost	Annual maintenance cost	Total annual costs(2)	Annual benefits	Benefit-cost ratio
Pine River	$684,500	$5,900	$58,100	$297,900	5.13
Pokegama	14,600	800	1,900	1,700	0.89
Sandy	8,757,600(3)	2,900	668,200	155,600	0.23
Winnibigoshish	259,700	1,600	21,400	0	0
Total	9,716,400	11,200	751,500	455,200	0.60

(1) Includes raising nine dikes identified previously.
(2) Based on a 100-year project life and a 7 5/8-percent interest rate and annual operation and maintenance costs.
(3) Approximately $8 million would be allocated to construct a new Sandy Lake control structure.

Upgrade perimeter dikes - detailed cost estimate (197[illegible] prices)

Item	Unit	Unit cost	Winnibigoshish Lake dikes Quantity	Cost	Pokegama Lake dikes Quantity	Cost	Sandy Lake dikes Quantity	Cost	[illegible] Lake dikes Quantity	Cost
Federal first cost										
Construction										
Grubbing and clearing	Acre	$1,000.00	2.2	$2,200	0.2	$200	4.7	34,700	7.1	47,100
Stripping and scarifying	CY	3.00	2,650	8,000	250	750	6,180	18,550	5,630	16,900
Gravel removal	CY	2.50	-	-	-	-	1,000	2,500	-	-
Bituminous removal	SY	2.50	-	-	-	-	5,300	13,250	-	-
Gravel placement	CY	11.00	-	-	-	-	1,000	11,000	-	-
Bituminous placement	SY	6.50	-	-	-	-	5,300	34,450	-	-
Impervious compacted fill	CY	6.00	10,900	65,400	270	1,600	24,000	144,000	1,100	6,600
Seeding	Acre	700.00	1.8	1,250	0.2	150	3.3	2,300	0.6	400
New structure	Each	4,500,000.00	-	-	-	-	1	4,500,000 (2)	-	-
Riprap	CY	25.00	2,050	51,250	165	4,200	3,700	92,500	10,500	262,500
Subbase	CY	15.00	1,027	15,400	80	1,200	1,850	27,750	5,650	84,800
Total construction				143,500		8,100		4,851,[illegible]		378,300
Contingencies				[illegible]		1,600		958,2[illegible]		75,700
Engineering and design				[illegible]		600		363,100		28,400
Supervision and administration				10,800		600		363,100		28,400
Total Federal first cost				193,300		10,900		6,535,500		510,800
Non-Federal first cost				0		0		0		0
Total first cost				193,300		10,900		6,535,500		510,800
Annualized first cost (6 5/8 percent interest and 100-year life = 0.06636 x total first cost)				12,100		700		433,700		33,900
Annual operation and maintenance costs				1,200		600		2,200		4,400
Total average annual cost				13,300		1,300		435,900		38,300
Total average annual benefits				[illegible]		[illegible]		11[illegible],100		22[illegible]
Benefit-cost ratio						[illegible]		[illegible]		.5[illegible]

[illegible]

Upgrade perimeter dikes - benefit-cost summary

Item	Winnibigoshish 1977 prices	Winnibigoshish 1981 prices	Pokegama 1977 prices	Pokegama 1981 prices	Sandy 1977 prices	Sandy 1981 prices	Pine River 1977 prices	Pine River 1981 prices
First cost	$193,800	$259,700	$10,900	$14,600	$6,535,500	$8,757,600	$510,800	$684,500
Annual O&M cost	1,200	1,600	600	800	2,200	2,900	4,400	5,900
Total annual cost (1)	13,300	21,400	1,300	1,900	435,900	671,100	38,300	58,100
Annual benefits	0	0	1,300	1,700	116,100	155,600	222,300	297,900
Benefit-cost ratio	0	0	1.0	0.89	0.27	0.23	5.80	5.13
Interest rate	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8

(1) Based on a 100-year life and includes O&M costs.

A lesser alternative would not include riprap protection or raising the nine dikes identified previously. This alternative would consist of simply grubbing and clearing trees and brush from all 28 dikes and providing annual maintenance on them. The detailed cost for this alternative is shown in the following table.

Maintain perimeter dikes - detailed cost estimate (1977 prices)

Item	Unit	Unit cost	Winnibigoshish Lake dikes Quantity	Winnibigoshish Lake dikes Cost	Pokegama Lake dikes Quantity	Pokegama Lake dikes Cost	Sandy Lake dikes Quantity	Sandy Lake dikes Cost	Pine River Lake dikes[1] Quantity	Pine River Lake dikes[1] Cost
Federal first cost										
Grubbing and clearing	Acre	$1,000.00	2.2	$2,200	0.2	$200	4.7	$4,700	7.10	$7,100
Contingencies				400		40		950		1,400
Engineering and design				150		30		350		500
Supervision and administration				150		30		350		500
Total Federal first cost				2,900		300		6,350		9,500
Non-Federal first cost				0		0		0		0
Total first cost				2,900		300		6,350		9,500
Annualized first cost (6 5/8 percent interest and 100-year life = 0.06636 x total first cost)				190		20		420		630
Annual operation and maintenance costs				1,200		600		2,200		4,400
Total average annual cost				1,390		620		2,620		5,030
Total average annual benefits				0		1,300		116,100		222,300
Benefit-cost ratio[2]				0		2.1		44.3		44.2

(1) No recommendations or cost estimates available for correcting dikes Nos. 13 and 14 seepage problem.
(2) Assumes no dike failure from the design flood.

Maintain perimeter dikes - benefit-cost ratio summary

	Winnibigoshish Lake dikes		Pokegama Lake dikes		Sandy Lake dikes		Pine River Lake dikes	
	1977 prices	1981 prices	1977 prices	1981 prices	1977 prices	1981 prices	1977 prices	1981 prices
First cost	$2,900	$3,900	$300	$400	$6,350	$8,500	$9,500	$13,000
Annual O&M costs	1,200	1,600	600	800	2,200	3,000	4,400	5,900
Total annual cost (1)	1,390	1,900	620	830	2,620	3,650	5,030	6,900
Annual benefits	0	0	1,300	1,700	116,100	155,600	222,300	298,800
Benefit-cost ratio	0	0	2.1	2.0	44.3	42.6	44.2	43.3
Interest rate	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8

(1) Based on 100-year life and including O&M costs.

BENEFITS

The benefits to be derived from an upgraded perimeter dike system are difficult to assess as the existing dikes have functioned well since their construction in the early 1900's. Of the 28 dikes, 21 are part of an existing county or access road system located in low population but high visitor use recreation areas.

The original construction objective of the dikes was to prevent loss of impounded water from the raised headwaters lakes. The dikes also presently afford some flood protection to adjoining property that could be subject to overflow if the dikes were not in place. If the present dikes were to fail, downstream roads could be adversely affected, the roadways on the dikes could be damaged, and a potential loss of life might occur as a result.

These flood control benefits are not easily defined without a detailed hydrologic analysis. Therefore, for this stage 2 report, it was decided that only low water damages would be used in a cost-benefit analysis. The low-water damage curves for each lake are already available in the section on problem 1 dealing with lake operating plans.

Average annual low water losses for each of the four lakes having perimeter dikes were developed by assuming that the most critical dike would fail and that lake water levels would revert to natural flow condition levels (or to some other level, if the scour elevation at the dike failure site was considerably different from the sill or natural outlet level for the main lake control site). The resulting lower levels were presumed to occur for 5 years until a new perimeter dike was in place.

The resulting average annual increase in low water damages using this approach was as follows:

Lake	Increased single event low water damages (1977 prices)	Increased average annual low water damages 1977 prices (1)	1981 prices (2)
Pine River	$3,350,000	$222,300	$297,900
Pokegama	20,000	1,300	1,700
Sandy	1,750,000	116,100	155,600
Winnibigoshish	0	0	0

(1) For 100-year life and 6 5/8 percent interest rate.
(2) For 100-year life and 7 5/8 percent interest rate.

The preceding table shows that a potential failure of Pine River and Sandy Lakes perimeter dikes is of greatest concern and would produce the most low water damages. These potential damages would be prevented by upgrading the perimeter dikes to prevent failure; this would be a principal benefit from this construction.

A discussion of each of the four lakes with perimeter dikes follows.

Pine River Lake (100 percent loss of water levels to natural conditions)

A failure of dike No. 14 (or 13) would cause downstream flooding in a series of lake areas, and water would enter the Pelican River south of the Whitefish Chain of Lakes. The Pelican River flows into the Little Pine River and then into the Mississippi River. The average annual summer low water levels could drop from 1227.0 to 1215.2.

Pokegama Lake (less than 100 percent loss of water levels to natural conditions)

Failure of dike No. 1 would perhaps lower the lake to only elevation 1172.5 or about one-half foot lower than the average annual summer low water under present conditions.

Sandy Lake (100 percent loss of water levels to natural conditions)

A failure of dike No. 2 (or possibly No. 1) would lower the average annual low water levels from elevation 1213.3 to approximately elevation 1209 on an average annual basis.

Winnibigoshish Lake (slight effect on average annual low water levels)

Failure of perimeter dikes Nos. 2, 3, and possibly 4 would allow Winnibigoshish Lake to flow south to Six Mile Lake and then into the Leech Lake River. However, the overflow section would be about the same elevation as the average annual low water level under present conditions (elevation 1298).

RECOMMENDED ACTION

Recommended actions for the headwaters lakes perimeter dikes are given below.

a. No further investigation of the 28 perimeter dikes is recommended in a stage 3 Mississippi River Headwaters Lakes Study report. The 28 perimeter dikes should be included for detailed inspection and testing in the District's regular scheduled maintenance program. The dikes that require additional height to meet standard project flood criteria could not be economically justified, except possibly those for Pokegama Lake. The Pine River Lake dikes which do not require raising but would require riprap protection appear to be economically justified.

b. Sixteen Pine River and two Pokegama Lake dikes should be scheduled for upgrading with riprap protection and/or raising as concluded in this study. The riprap protection work would be accomplished under the present operation and maintenance program authority. However, the Corps would have to obtain additional authority to pursue raising any perimeter dikes. The remaining 10 perimeter dikes on Pokegama Lake and other areas should be cleared of brush and trees and properly monumented, with the exception of dike No. 1 at Lake Winnibigoshish. This dike could not be located under an existing roadway.

c. A Flood Assurance Program was initiated by the Corps of Engineers in response to an Executive Memorandum dated 23 April 1977. The memorandum was addressed to all agencies and departments and concerned dam safety. The new program essentially requires Corps dams to meet the same standards as non-Federal dams. The perimeter dikes could be included in further evaluations under this relatively new program. This program is separate from the 1972 National Dam Safety Act that applied only to non-Federal dams.

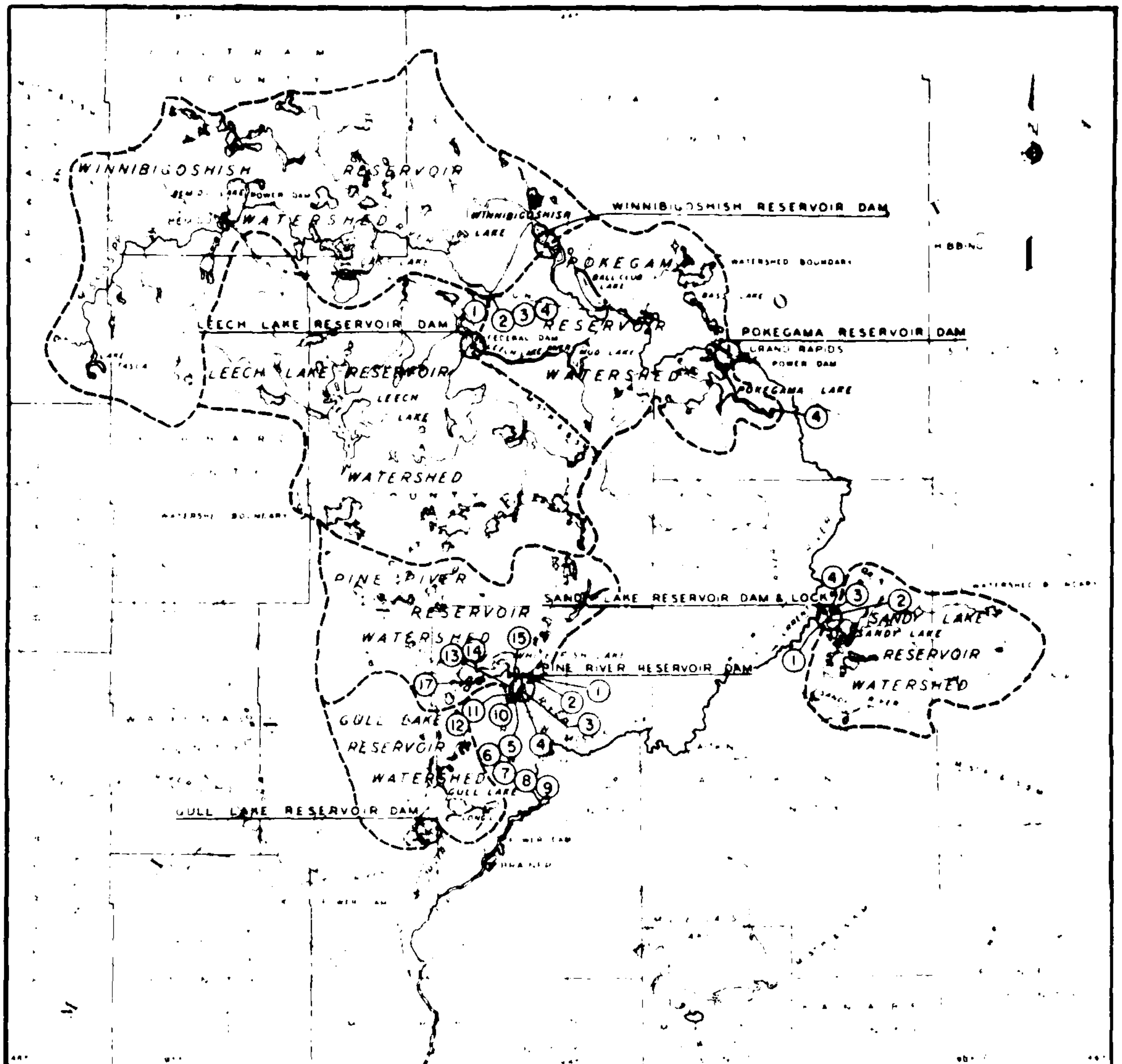
d. Dikes Nos. 13 and 14 at the Pine River Lakes area meet the standard project flood design height criteria but have a special seepage problem. Seepage of 5 to 20 cfs at various locations downstream of these two dikes was observed during an October 1977 field inspection. Free seepage from the dike toes and natural abutment materials between dikes Nos. 13 and 14 was observed during that inspection. The seepage has occurred for some time and causes the area to stay open all winter. The seepage is thought to result because the dike was built on natural ground that was not first stripped of the overlying vegetative material.

One boring was taken in the area and several more should be scheduled to determine the physical characteristics of the embankment material and the seepage potential through the dike. Field personnel were instructed to monitor the situation monthly and to observe and report any changes. A permanent solution to the seepage problem should be developed and implemented under the Corps operation and maintenance authority.

e. Additional survey is needed to locate all of the dikes in plan view. The survey would locate the ends of each dike and monument them for future reference and for possible acquisition of property. The dikes should then be recorded on site plan maps of sufficiently detailed scale. Additional dike cross section work is also required to better define accurate work quantities. The 28 dikes should all be cleared of brush and trees prior to monumentation with the exception of dike No. 1 at Winnibigoshish Lake which could not be located under an existing roadway.

PLATE SUMMARY

Number	Item
A-95	Earth dikes (location map).
A-96	Sandy Lake Dam, construction of access road, general plan and borings.
A-97	Detailed dike location map, Winnibigoshish Lake.
A-98	Detailed dike location map, Pokegama Lake.
A-99	Detailed dike location map, Sandy Lake.
A-100	Detailed dike location map, Pine River Lake.
A-101	Dike No. 13, Cross Lake-Pine River dike profiles and sections.
A-102	Dike No. 14, Cross Lake-Pine River dike profiles and sections.



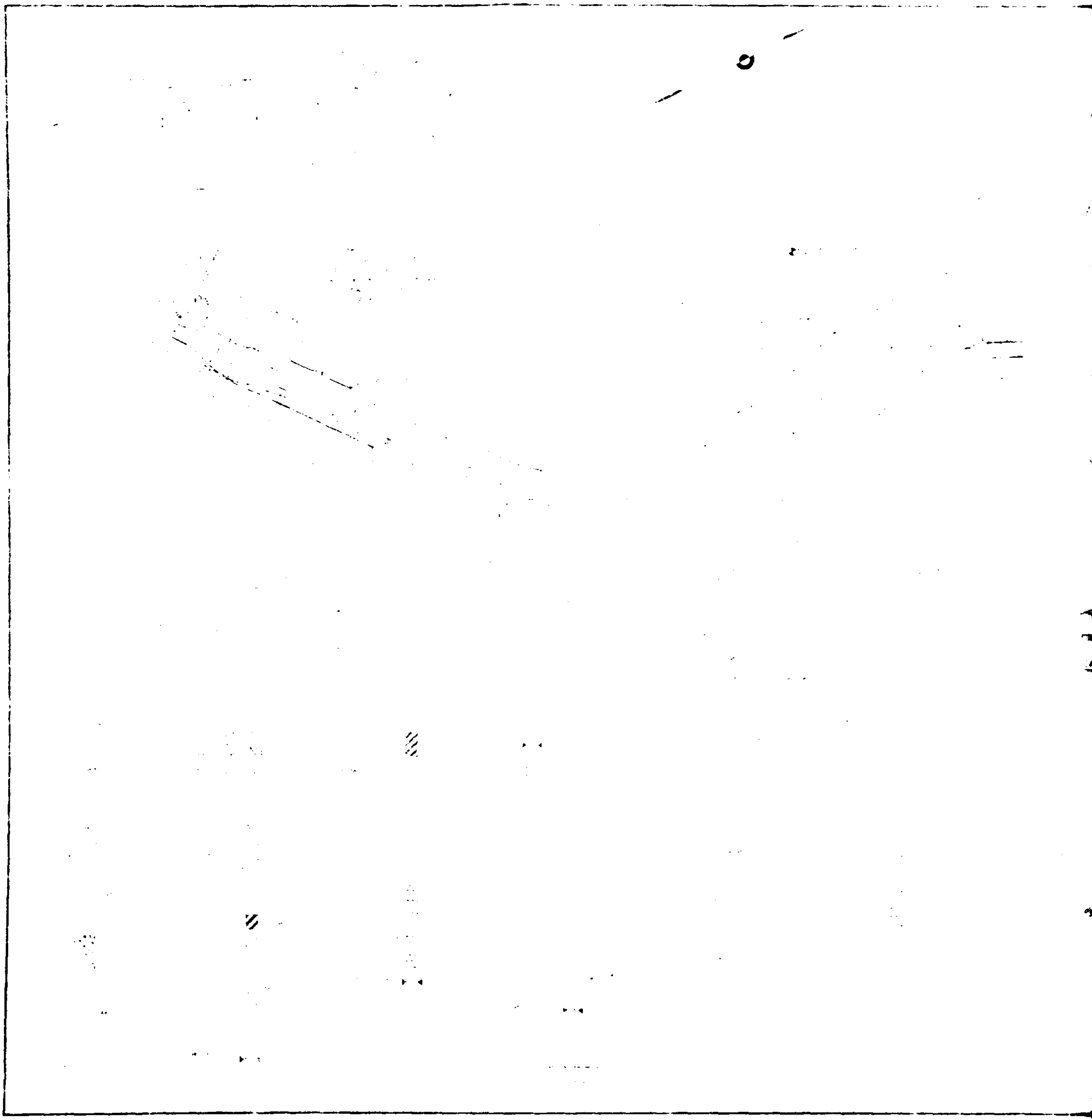
LOCATION		[illegible]	Top Elevation
WINNIBIGOSHISH LAKE RESERVOIR	Main earth dam-South portion	750'	[illegible]
	Main earth dam-North portion	50'	[illegible]
	Dike No. 1	1707'	[illegible]
	Dike No. 2	400'	[illegible]
	Dike No. 3	770'	[illegible]
	Dike No. 4	420'	[illegible]
LEECH LAKE RESERVOIR	Main earth dam	3180'	[illegible]
POKEGAMA LAKE RESERVOIR	Main earth dam-West portion	60'	1278.3
	Main earth dam-East portion	[illegible]	1278.3
	Dike No. 4	108'	1282.0
SANDY LAKE RESERVOIR	Main earth dam-North portion	75'	1223.0
	Main earth dam-South portion	30'	1225.3
	Dike No. 1 (Access road)	1388'	[illegible]
	Dike No. 2	250'	1227.0
	Dike No. 3	[illegible]	1227.0
	Dike No. 4 (Aitkin Lake road)	1200'	1225.0
PINE RIVER RESERVOIR	Main earth dam-West portion	210'	[illegible]
	Main earth dam-East portion	800'	[illegible]
	Dike No. 1	800'	[illegible]
	Dike No. 2	500'	[illegible]
	Dike No. 3	800'	[illegible]
	Dike No. 4	200'	[illegible]
	Dike No. 5	900'	[illegible]
	Dike No. 6	1000'	[illegible]
	Dike No. 7	250'	[illegible]
	Dike No. 8	900'	[illegible]
	Dike No. 9	300'	[illegible]
	Dike No. 10	260'	[illegible]
	Dike No. 11	600'	[illegible]
	Dike No. 12	150'	[illegible]
	Dike No. 13	1000'	[illegible]
	Dike No. 14	[illegible]	[illegible]
	Dike No. 15	[illegible]	[illegible]
	Dike No. 17	100'	[illegible]
GULL LAKE RESERVOIR	Main earth dam-West portion	90'	[illegible]
	Main earth dam-East portion	[illegible]	[illegible]
		[illegible]	[illegible]
		[illegible]	[illegible]

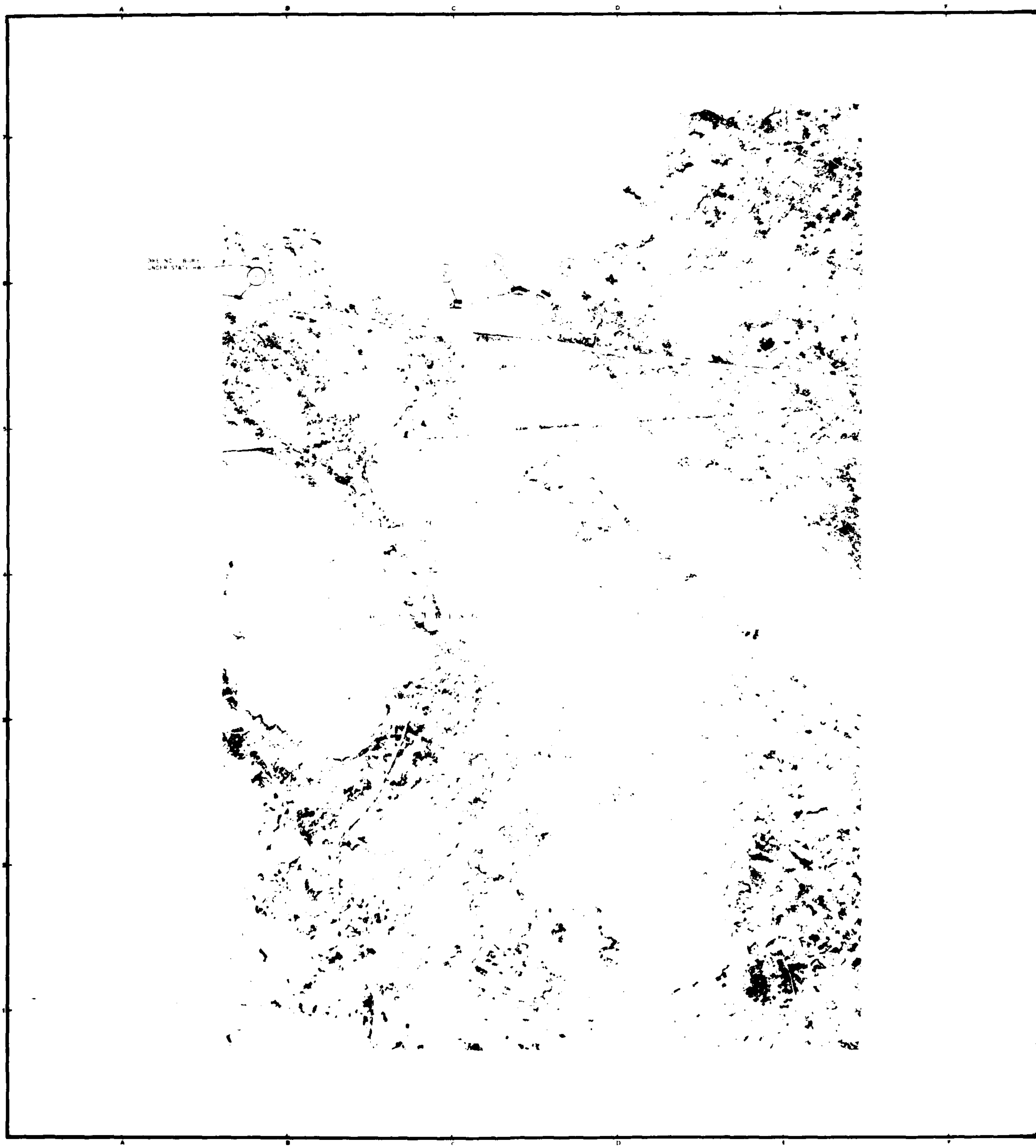
4 – DIKE NUMBER AND LOCATION

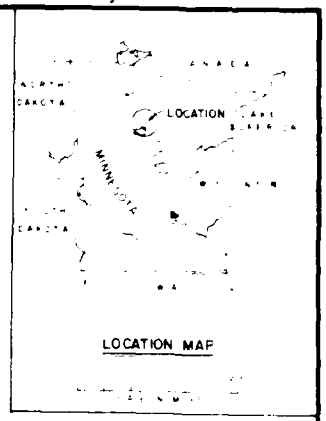
20 MILES

MISSISSIPPI RIVER
HEADWATER NAVIGATION RESERVOIRS
EARTH DIKES

Plate A-95




A
B
C
D
E
F



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

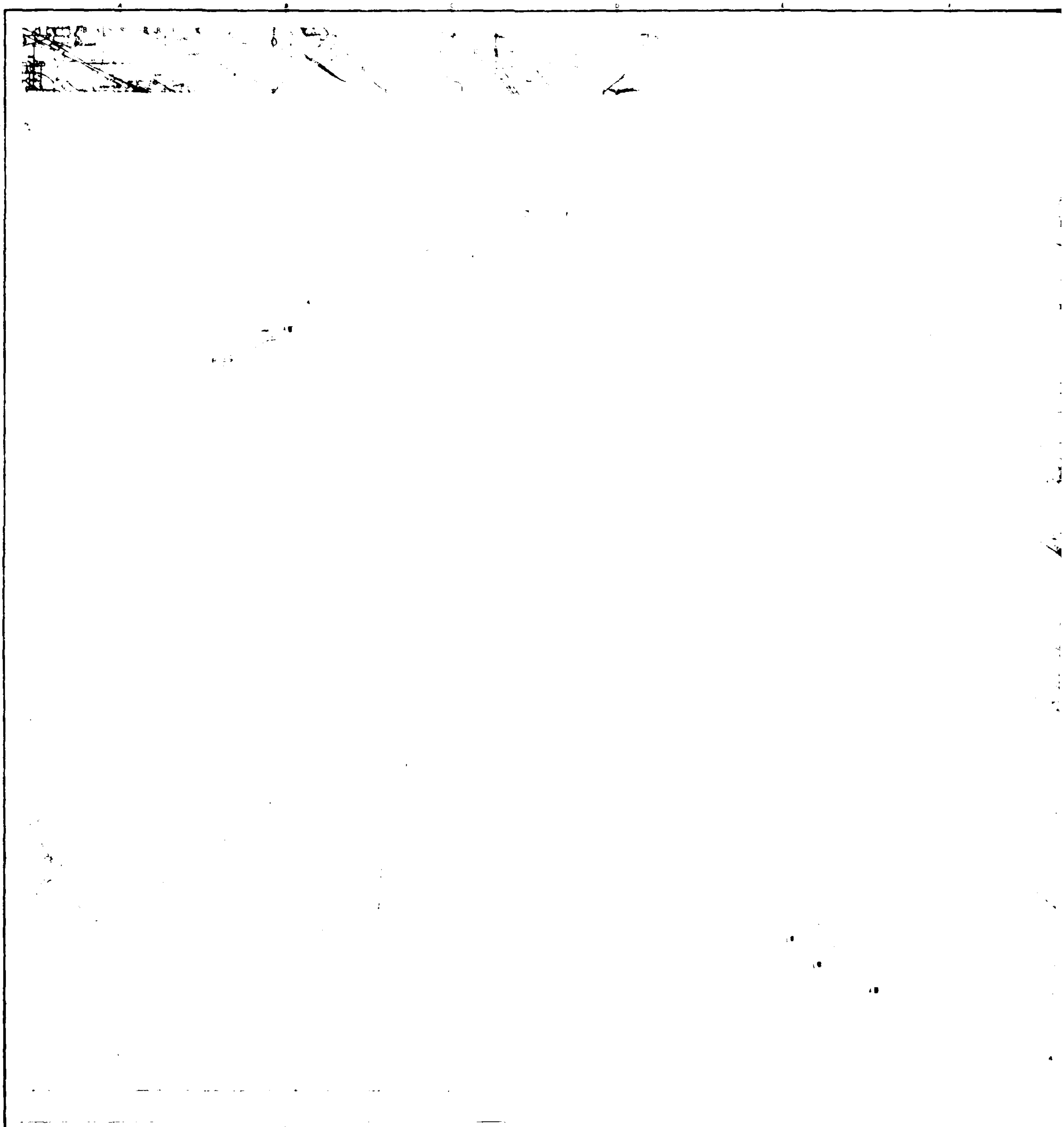
MISSISSIPPI RIVER HEADWATER STUDY
LAKE WINNIBIGOSHISH
PERIMETER DIKES
LOCATION MAP

DATE

DRAWING NUMBER

SHEET 1 OF

PLATE A-97



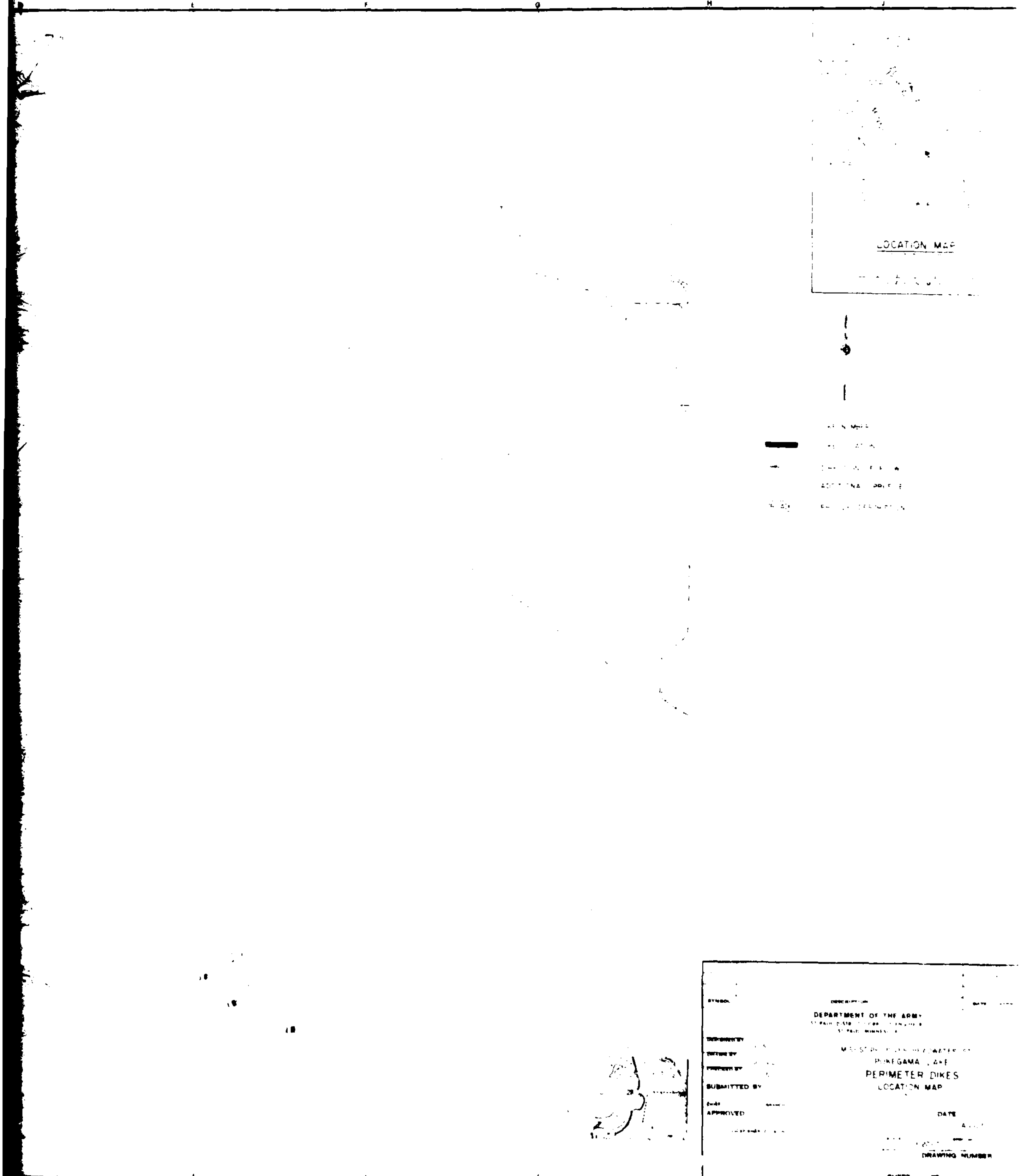

LOCATION MAP
SYMBOL
DESCRIPTION
DATE
DEPARTMENT OF THE ARMY
SUBMITTED BY
APPROVED
PERIMETER DIKES
LOCATION MAP
DATE
DRAWING NUMBER
SHEET
OF 4

PLATE A-

RPS OF ENGINEERS

NOTE

SYMBOL

DEPARTMENT OF THE ARMY

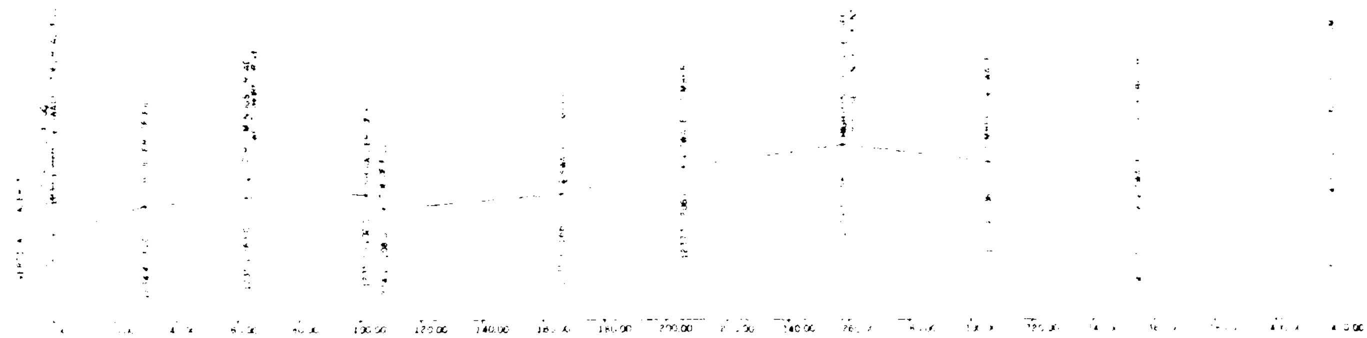
DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
CHIEF
APPROVED

SAND LAKE
PERIMETER DIKES
LOCATION MAP

DATE

DRAWING NUMBER

SHEET OF



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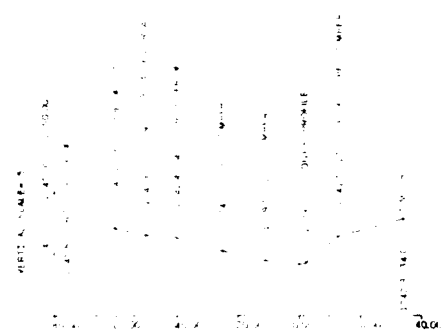
CROSS SECTION



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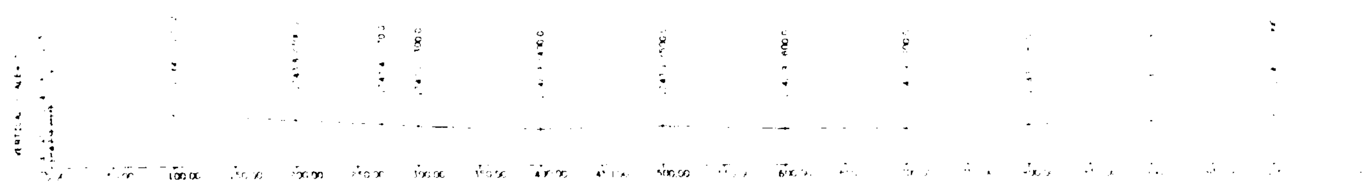
POINT OF DIVIDE
CROSS SECTION



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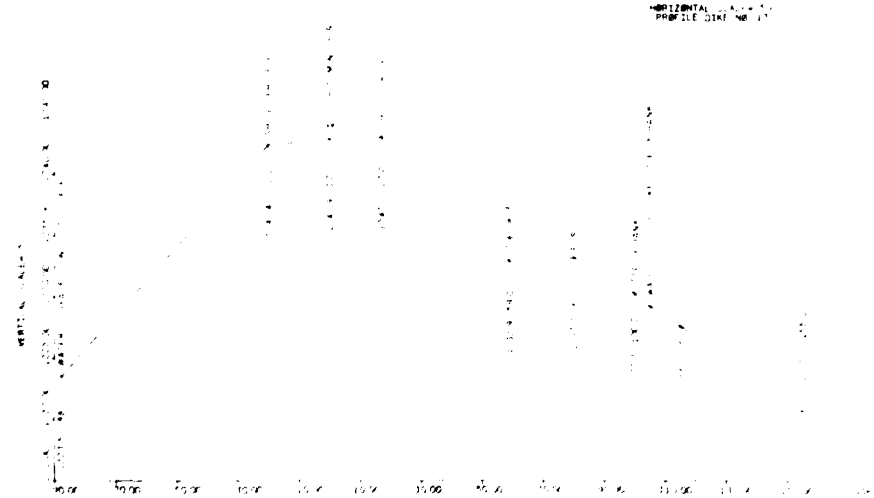

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DIKE
CROSS SECTION

DATUM

FIELD NOTES
ALIGNMENT
PAGE

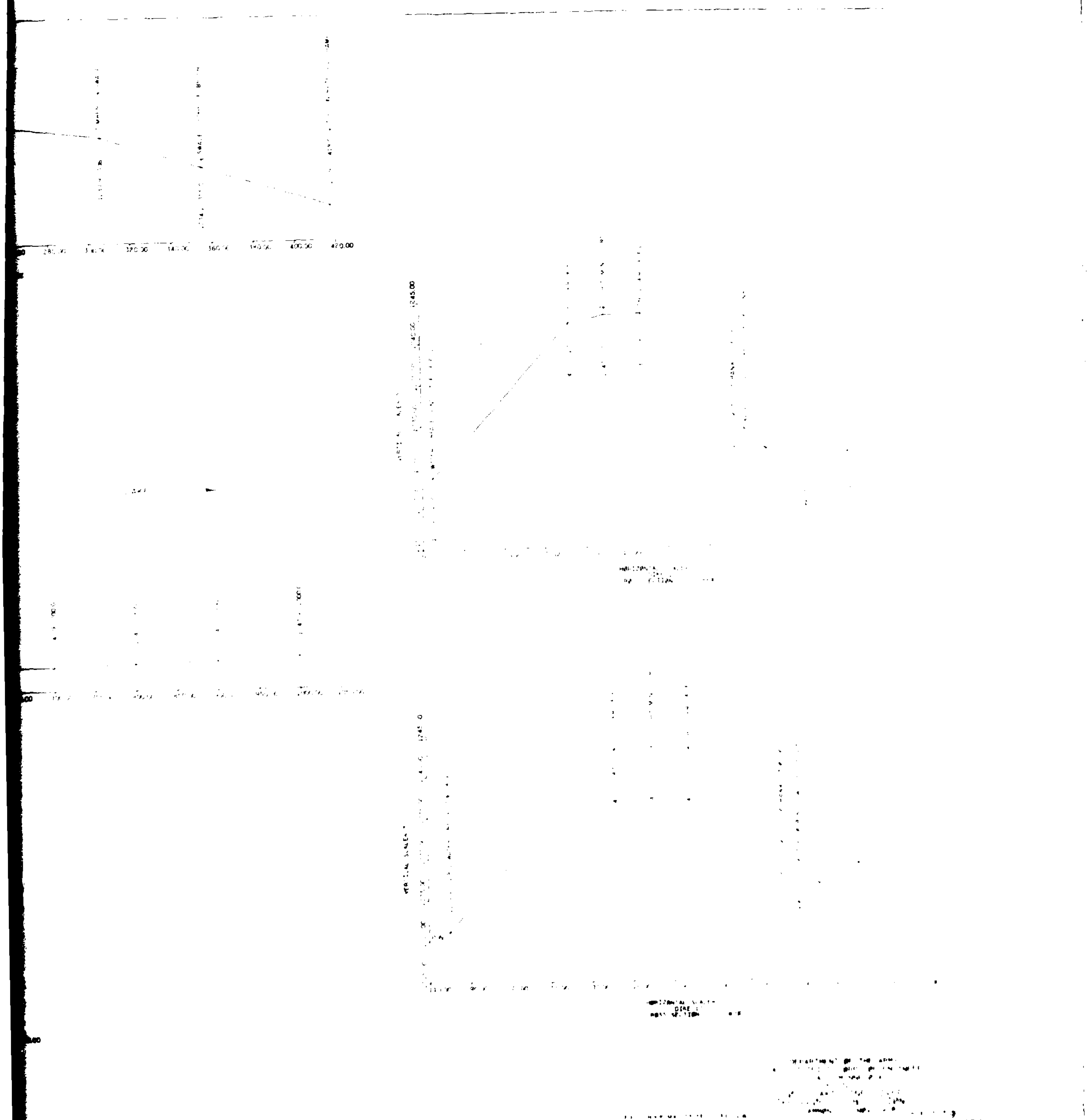
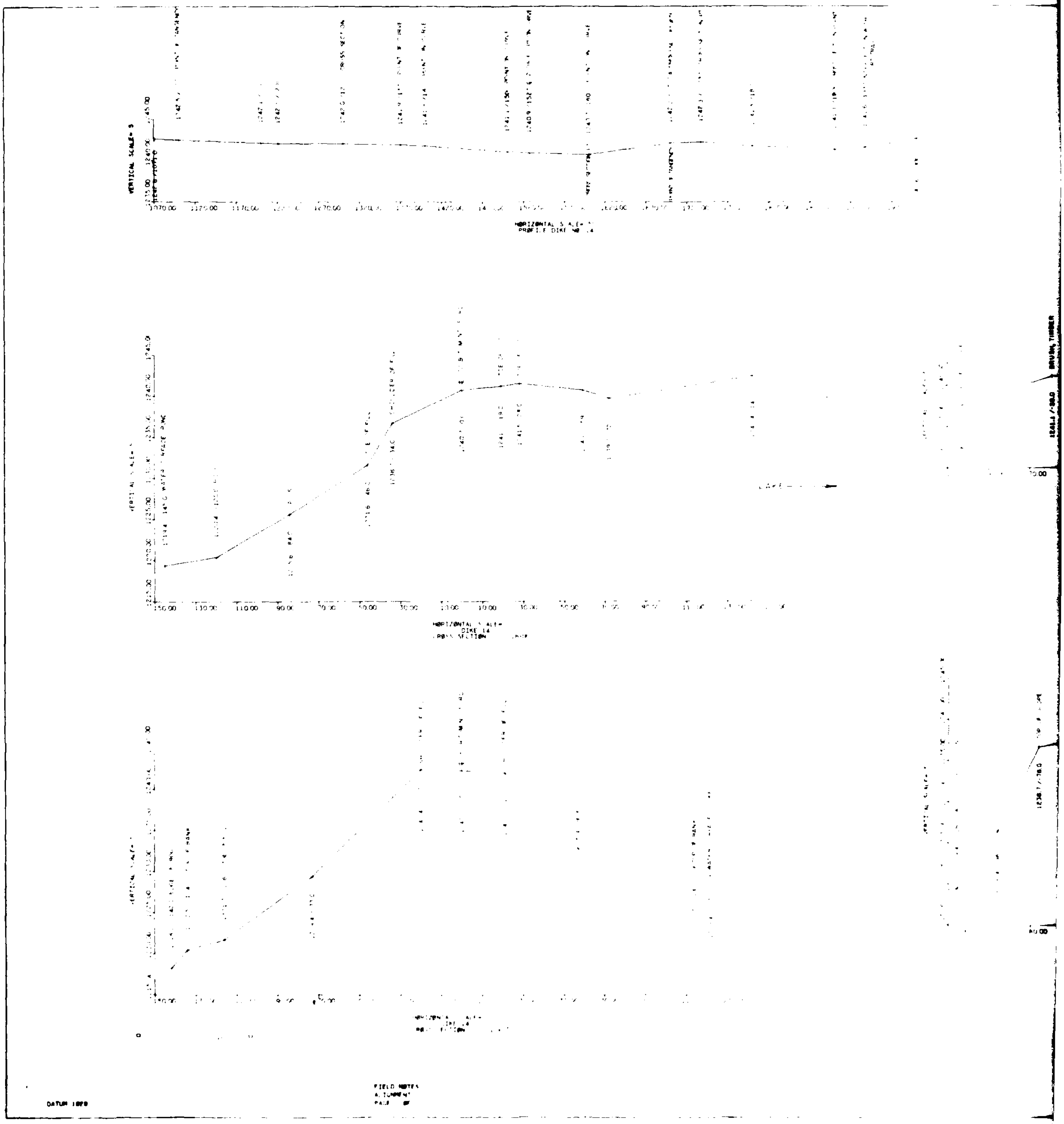


PLATE A-101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DIKE 14
CROSS SECTION
SHOULDER OF FILL
BRUSH, TIMBER
DATUM 1929
FIELD NOTES

DEPARTMENT OF THE ARMY

PROBLEM 7 - WHITEFISH LAKE CHANNEL OBSTRUCTIONS AND MARKING

BACKGROUND

The Pine River Dam at Cross Lake controls the levels of 12 lakes known locally as the Whitefish Chain of Lakes. The Pine River Dam was constructed and placed in operation during the period 1884-1887 and was replaced by a concrete structure between 1905 and 1908.

Tree stumps and sandbars in connecting channels between several lakes of the Whitefish Chain provide a hazard to boats during low water periods such as occurred in 1976. In some cases the connecting channels are very narrow and tend to silt in fairly rapidly due to littoral drift. The connecting lake inlets provide serious problems to boats moving from one lake to another.

The 1976 low water receded to 1227.7 in October in the Whitefish Chain of Lakes. This level, although lower than normal, was well above the desirable minimum lower operating level of the lake chain (elevation 1227.32). The Trout Lake to Lower Whitefish Lake area was a major problem during this period.

Present desirable operating levels for the Whitefish Chain of Lakes are from 1229.07 to 1229.57 during the recreation season and from 1227.32 to 1230.32 during the remainder of the year. Operation of the Whitefish Lakes originally varied from 1217.62 to 1234.82, but in the 1930's these maximum limits were revised to 1225.31 to 1231.32 by War Department regulations.

GEOLOGY AND SOILS

No formal program of subsurface investigations was conducted for this area due to funding constraints. A detailed sampling regime for chemical and total particle size has been recommended. The sampling program would probe the proposed depth of elevations, with sample cores taken every 500 feet. The cost of this program is estimated at over $27,000. The information obtained from this program will also provide valuable soils information.

HYDROLOGY AND HYDRAULIC STUDIES

At several area meetings in 1977, at least 20 problem sites were identified by local property owners as requiring some form of improvement. Six of the 20 sites were further identified as possibly justifying Federal cost sharing for construction. Benefits relating to structural improvement could be defined for these six sites, whereas the other identified sites could not be justified. The 20 locations are shown on plate A-96.

The six channels previously discussed would be dredged and lined with riprap, forming jetties on either side of the channels. The length of jetties was determined for each location based on the individual site characteristics and orientation to the prevailing wind direction. The location and length of jetties were further determined based on evaluation of sediment buildup at each channel location over a period of 19 years. Aerial photographs of 1957 and 1976 and U.S. Geological Survey quadrangle sheets for the period 1959-1960 were used to estimate the rate of accretion in the channel locations. The six channel sites are shown on plates A-97 through A-100.

Further investigation revealed that the Minnesota Department of Natural Resources had also constructed a similar type of channel improvement between Upper Whitefish and Arrowhead Lakes in 1960. (The location of this latter work is shown on plate A-97.) The manner of accretion from littoral drift and the manner of scour taking place at the Department of Natural Resources site were also used as a guide to develop preliminary designs for cost estimates.

The six Whitefish Lake channels were designed to have a 6.0-foot depth below the minimum operating level of 1227.07. This alternative would provide adequate depth for boats traveling these channels. The 6-foot low water depth is a minimum recommended in the December 1974,

U.S. Army Corps of Engineers Special Report No. 2, Design, Construction, and Operation of Small-Craft Harbors. This report recommends a minimum channel width of 50 feet or five times the beam width of the widest boat using the area. Extra width is required if sailboats use the channel.

The alternatives investigated used 40-foot and 75-foot channel bottom widths. The 40-foot width seemed to be most desirable to Whitefish Lake property owners, and the 75-foot width met the beam width criteria of the Corps of Engineers. The 75-foot bottom width channel is recommended wherever it is economically feasible, and a 40-foot bottom is recommended where the 75-foot bottom is not feasible. The dredged channels would have 1V on 3H side slopes. Riprap jetties would be placed on each side of the excavated channels, and the dredged material would be placed on the outside or landward side of the jetties. The dredged material would be moved by dragline and, in most instances, would be placed partially on land and partially in water areas adjacent to the jetties.

The dredged material would consist primarily of sand and other lake sediments and would be used to build up land access to the riprap jetty piers. The piers could provide fishing access as well as a boat channel passage between the lakes. The six jetty and disposal areas and typical cross sections are shown on plates A-101 through A-104. A design aid showing prevailing wind directions is also shown on plate A-105.

General comments and length of design channel at each location based on the above sources and on field inspections of the area follow.

<u>Bertha Lake to Whitefish Lake.</u> - The proposed site has a fairly stable shoreline on both sides of the proposed channel. The proposed channel and two jetty lengths are 300 feet. There is a Corps public access on this lake. Channel bottom would be 75 feet wide at 6 feet below elevation 1227.07 (2 feet below minimum summer pool), with side slopes 3H to 1V.

Lower Hay Lake to Whitefish Lake. - Some sediment transport and shoaling are occurring at this location. Littoral drift moves from west to east along the connecting sand spot. A 300-foot channel and jetty length was used but consideration should be given to using a longer jetty leg on the west side of the channel extending into Whitefish Lake during the detailed design stage. There is a Corps public access on this lake. Channel bottom would be 75 feet wide at 6 feet below elevation 1227.07 (2 feet below minimum summer pool), with side slopes of 3H to 1V.

Big Trout Lake to Whitefish Lake. - Actual experience with limited dredging efforts by local people at this location indicates that this channel area can fill in again in a matter of months if the work is not done properly. Accretion can be expected on the east side of the channel in Whitefish Lake. Prevailing southwest winds move sand directly into the present channel. There is a Corps public access on Big Trout Lake. A 300-foot-long channel is proposed with a 75-foot bottom width at 6 feet below elevation 1227.07 (2 feet below minimum summer pool), with channel side slopes of 3H to 1V.

Pig Lake (East Bay) to Whitefish Lake. - This area has not been dredged since 1957 and possibly not before that. A 200-foot-long channel and jetty should be adequate. A 40-foot channel bottom width at 6 feet below elevation 1227.07 (2 feet below minimum summer pool) and 3H on 1V side slopes are proposed for this location. A 75-foot bottom at a lower depth is not economically feasible.

Island Lake to Whitefish Lake. - The lake access opening is narrowing as accretion builds slowly on the north and south sand points. The progression of buildup to the east is insignificant. A 300-foot channel length and jetties are proposed. Channel bottom width would be 75 feet at 6 feet below elevation 1227.07 (2 feet below minimum summer pool), with 3H on 1V channel side slopes.

Loon Lake to Island Lake. - The growth of land or buildup from Island Lake to Loon Lake appears to be about 350 feet in about 19 years, or about 18 feet on the average. The progressive buildup is largely northeastward to Loon Lake. A 600-foot channel length and jetties are proposed here. Channel bottom width would be 40 feet at 6 feet below elevation 1227.07, with 3H on 1V side slopes. A 75-foot bottom at a lower depth is not economically feasible at this site.

COST ESTIMATE

Preliminary construction cost estimates are presented in the following tables for each of the six proposed channel work sites. All initial costs in October 1977 price levels are indexed to October 1981. Interest is at 7 5/8 percent with a 50-year project life. A summary table for all six sites precedes the detailed cost summaries.

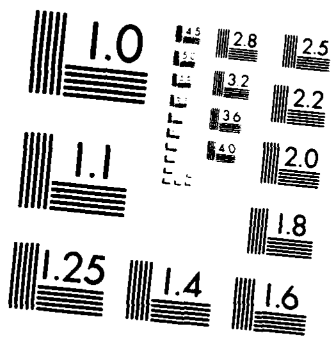
Benefit-cost summary - Whitefish Lakes connecting channels(1)

Item	Bertha 1977 prices	Bertha 1981 prices	Lower Hay 1977 prices	Lower Hay 1981 prices	Big Trout 1977 prices	Big Trout 1981 prices	Pig (East Bay) 1977 prices	Pig (East Bay) 1981 prices	Island 1977 prices	Island 1981 prices	Loon 1977 prices	Loon 1981 prices
First cost	$182,800	$245,000	$174,300	$233,600	$190,700	$255,500	$70,600	$94,600	$187,300	$251,000	$112,400	$150,600
Annual cost	21,600	31,400	17,400	25,600	24,300	35,000	9,300	13,400	29,600	30,200	15,600	22,400
Annual benefit	112,000	177,750	60,100	95,400	117,600	186,525	11,000	17,325	35,500	56,325	16,400	26,025
Benefit-cost ratio	5.18	5.66	3.45	3.73	4.84	5.33	1.18	1.29	1.72	1.87	1.05	1.16
Interest rate	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8	6 5/8	7 5/8

(1) NOTE: 75-foot bottom width channels except for East Bay Pig Lake and Loon Lake, which are 40-foot bottoms. Design water surface = 1,227.07 with clamshell dredging. Project life - 50 years. Interest rate - 7 5/8 percent.

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA 4/8
FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST
PAUL MN ST PAUL DISTRICT SEP 82

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Estimate of construction costs

Item	Unit	Quantity	Unit cost	Total cost (1977 prices)
Bertha to Whitefish				
Federal first costs				
Mobilization	Lump sum	-	-	$1,000
Clearing	Lump sum	-	-	400
Dredging	CY	3,860	$5.00	19,300
Riprap	CY	3,600	25.00	90,000
Polyfilter	SF	25,200	0.50	12,600
Contingencies				24,700
Engineering and design				11,100
Supervision and administration				11,100
Total Federal first cost				170,200
Non-Federal first costs				
Lands	Acre	4.0	2,000.00	8,000
Acquisition	Lump sum	-	-	2,500
Contingencies				2,100
Total non-Federal first cost				12,600
Total first costs				182,800

Federal annual charges

Interest and amortization ($170,200 x 0.06909)(1)	$11,800	
Operation and maintenance cost (assume 50 percent redredging every 2 years, 50-year project life) $(12.078)^{(2)} \times (\frac{\$19,300}{2} + \$1,000) = \$128,600$		
0.06909 x $128,600	8,900	
Total Federal annual charges		20,700
Non-Federal annual charges - interest and amortization ($12,600 x 0.06909)		900
Total annual charges		21,600
Annual benefits		112,000
Benefit-cost ratio		5.2

Estimate of construction costs (cont)

Item	Unit	Quantity	Unit cost	Total cost
				(1977 prices)
Lower Hay Lake to Whitefish				
Federal first costs				
Mobilization	Lump sum	-	-	$1,000
Dredging	CY	2,200	$5.00	11,000
Riprap	CY	3,600	25.00	90,000
Polyfilter	SF	25,200	0.50	12,600
Contingencies				22,900
Engineering and design				10,300
Supervision and administration				10,300
Total Federal first costs				158,100
Non-Federal first costs				
Lands	Acre	5.5	2,000.00	11,000
Acquisition	Lump sum	-	-	2,500
Contingencies				2,700
Total Non-Federal first costs				16,200
Total first costs				174,300
Federal annual charges				
Interest and amortization ($158,100 x 0.06909)(1)			10,900	
Operation and maintenance cost (assume 50 percent redredging every 2 years 50-year project life) $(12.078)^{(2)} \times \left(\frac{\$11,000}{2} + \$1,000\right) = \$78,500$				
0.06909 x $78,500			5,400	
Total Federal annual charges				16,300
Non-Federal annual charges - interest and amortization ($16,200 x 0.06909)				1,100
Total annual charges				17,400
Annual benefits				60,100
Benefit-cost ratio				3.45

Estimate of construction costs (cont)

Item	Unit	Quantity	Unit cost		Total cost (1977 prices)
Big Trout to Whitefish					
Federal first costs					
Mobilization	Lump sum	-	-		$1,000
Clearing	Lump sum	-	-		800
Dredging	CY	4,930	$5.00		24,700
Riprap	CY	3,600	25.00		90,000
Polyfilter	SF	25,200	0.50		12,600
Contingencies					25,800
Engineering and design					11,600
Supervision and administration					11,600
Total Federal first costs					178,100
Non-Federal first costs					
Lands	Acre	4.0	2,000.00		8,000
Acquisition	Lump sum	-	-		2,500
Contingencies					2,100
Total Non-Federal first cost					12,600
Total first costs					190,700
Federal annual charges					
Interest and amortization ($178,100 x 0.06909)(1)				$12,300	
Operation and maintenance cost (assume 50 percent redredging every 2 years, 50-year project life) $(12.078)^{(2)} \times (\frac{\$24,700}{2} + \$1,000) = \$161,200$					
0.06909 x $161,200				11,100	
Total Federal annual charges					23,400
Non-Federal annual charges - interest and amortization $12,600 x 0.06909					900
Total annual charges					24,300
Annual benefits					117,600
Benefit-cost ratio					4.84

Estimate of construction costs (cont)

Item	Unit	Quantity	Unit cost	Total cost (1977 prices)
East Bay Pig Lake to Whitefish				
Federal first costs				
Mobilization	Lump sum	-	-	$1,000
Dredging	CY	1,725	$5.00	8,600
Riprap	CY	1,200	25.00	30,000
Polyfilter	SF	8,400	0.50	4,200
Contingencies				8,800
Engineering and design				3,900
Supervision and administration				3.900
Total Federal first cost				60,400
Non-Federal first costs				
Lands	Acre	3.0	2,000.00	6,000
Acquisition	Lump sum	-	-	2,500
Contingencies				1.700
Total non-Federal first cost				10,200
Total first costs				70,600
Federal annual charges				
Interest and amortization ($60,400 x 0.06909)(1)			$4,200	
Operation and maintenance cost (assume 50 percent redredging every 2 years, 50-year project life) (12.078)(2) x($8,600/2 + $1,000) = $64,000				
0.06909 x $64,000			4,400	
Total Federal annual charges				8,600
Non-Federal annual charges - interest and amortization ($10,200 x 0.06909)				700
Total annual charges				9,300
Annual benefits				11,000
Benefit-cost ratio				1.18

Estimate of construction costs (cont)

Item	Unit	Quantity	Unit cost	Total cost (1977 prices)
Island to Whitefish				
Federal first costs				
Mobilization	Lump sum	-	-	$1,000
Dredging	CY	3,230	$5.00	16,200
Riprap	CY	3,840	25.00	96,000
Polyfilter	SF	26,800	0.50	13,400
Contingencies				25,300
Engineering and design				11,400
Supervision and administration				11,400
Total Federal first costs				174,700
Non-Federal first costs				
Lands	Acre	4.0	2,000.00	8,000
Acquisition	Lump sum	-	-	2,500
Contingencies				2,100
Total non-Federal first costs				12,600
Total first costs				187,300

Federal annual charges

Interest and amortization ($174,700 x 0.06909)(1)	$12,100	
Operation and maintenance cost (assume 50 percent redredging every 2 years - 50-year project life) (12.078)(2) x ($\frac{\$16,200}{2}$ + $1,000) = $109,900		
0.06909 x $109,900	7,600	
Total Federal annual charges		19,700
Non-Federal annual charges - interest and amortization ($12,600 x 0.06909)		900
Total annual charges		20,600
Annual benefits		35,500
Benefit-cost ratio		1.72

Estimate of construction costs (cont)

Item	Unit	Quantity	Unit cost	Total cost (1977 prices)
Loon to Island				
Federal first costs				
Mobilization	Lump sum	-	-	$1,000
Dredging	CY	3,325	$5.00	16,600
Riprap	CY	1,920	25.00	48,000
Polyfilter	SF	13,440	0.50	6,700
Contingencies				14,500
Engineering and design				6,500
Supervision and administration				6,500
Total Federal first costs				99,800
Non-Federal first costs				
Lands	Acre	4.0	2,000.00	8,000
Acquisition	Lump sum	-	-	2,500
Contingencies				2,100
Total non-Federal first cost				12,600
Total first costs				112,400
Federal annual charges				
Interest and amortization ($99,800 x 0.06909)(1)			$6,900	
Operation and maintenance cost (assume 50 percent redredging every 2 years - 50-year project life) $(12.078)^{(2)} \times (\frac{\$16,600}{2} + \$1,000) = \$112,300$				
0.06909 x $112,300			7,800	
Total Federal annual charges				14,700
Non-Federal annual charges - interest and amortization ($12,600 x 0.06909)				900
Total annual charges				15,600
Annual benefits				16,400
Benefit-cost ratio				1.05

(1) Equal payment series capital recovery factor for 50 interest periods and 6 5/8-percent interest.

(2) Equal payment series present worth factor for 25 interest periods and 6 5/8-percent interest.

BENEFITS

Benefits for the proposed channel projects involving Whitefish Lake were derived using a simple approach. Natural channel passages from the main Whitefish Lake to each of the satellite lakes investigated tend to shoal in due to wind and wave action and littoral drift. A significant decrease in property values on the satellite lakes has occurred because guaranteed access to the main Whitefish Lake cannot be maintained. This loss varies from $70 to $90 per foot of shoreline property based on 1973 surveys of lakes in the immediate area. If complete access to the main Whitefish Lake were lost, the property owners on the seven lakes listed in the following table would sustain losses in property values amounting to $9,536,100, based on $70 per foot decrease in value.

Benefit derivation

Lake	Total shoreline (miles)	Property value loss	Annual benefit(1)
Bertha (includes Clamshell)	8.2	$3,030,700	$237,000
Lower Hay	4.4	1,626,600	127,200
Big Trout	8.6	3,178,600	248,700
Pig (East Bay)	0.8	295,700	23,100
Island	2.6	961,000	75,100
Loon	1.2	443,500	34,700
Total	25.8	9,536,100	745,800

(1) Annualized property value loss at 7 5/8-percent interest and 50-year life.

Annual benefits in the previous table were reduced by 25 percent for use in all benefit-cost comparisons. It was assumed that 100 percent of possible annual benefits could not reasonably be obtained with the improved channels, because they would silt in gradually or during severe storms. Thus, 75 percent of the possible benefits, as shown in the following table, were used in the benefit-cost comparison.

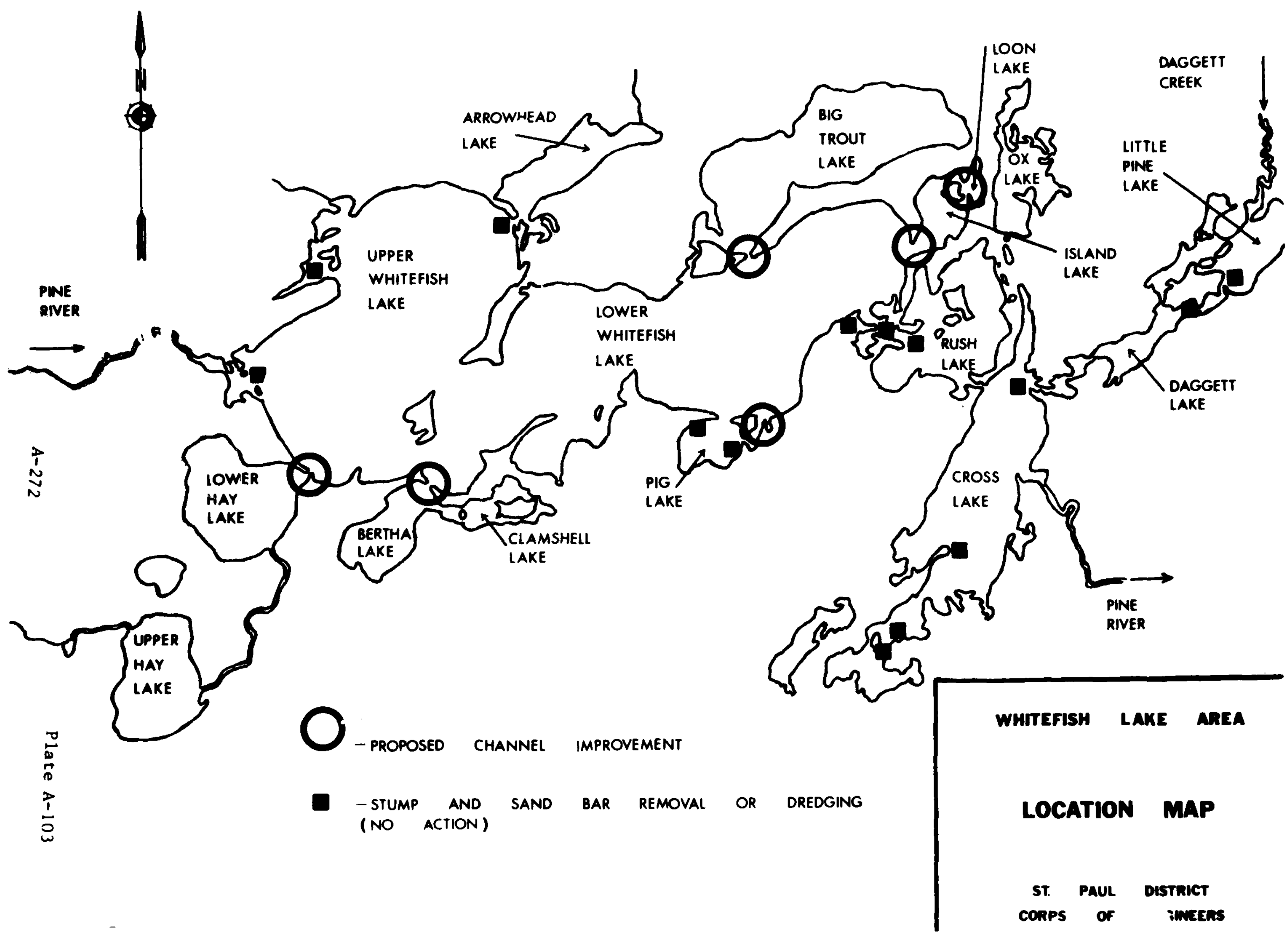
Lake site	Annual benefit
Bertha	$177,750
Lower Hay	95,400
Big Trout	186,525
Pig (East Bay)	17,325
Island	56,325
Loon	26,025
Total	559,350

RECOMMENDED ACTION

Permanent connecting channels at six locations in the Whitefish Chain of Lakes are economically feasible. These six connecting channels could be dredged to provide adequate width and depth at low water elevations. The channels would be paralleled, as required, by rock jetties to insure permanence and provide shore access for fishing. An authorized local sponsor has not agreed to support this proposal; thus, the project is not recommended for further study. If a suitable sponsor were found, the project could be investigated further under the small projects authority.

PLATE SUMMARY

Number	Item
A-103	Location map, Whitefish Lake area
A-104	Aerial location
A-105	Aerial location
A-106	Aerial location
A-107	Aerial location
A-108	Jetty and disposal map
A-109	Jetty and disposal map
A-110	Jetty and disposal map
A-111	Typical channel cross sections
A-112	Wind rose



N
ARROWHEAD LAKE
BIG TROUT LAKE
LOON LAKE
DAGGETT CREEK
OX LAKE
LITTLE PINE LAKE
ISLAND LAKE
PINE RIVER
UPPER WHITEFISH LAKE
LOWER WHITEFISH LAKE
RUSH LAKE
DAGGETT LAKE
CROSS LAKE
PIG LAKE
LOWER HAY LAKE
BERTHA LAKE
CLAMSHELL LAKE
PINE RIVER
UPPER HAY LAKE
– PROPOSED CHANNEL IMPROVEMENT
– STUMP AND SAND BAR REMOVAL OR DREDGING (NO ACTION)
WHITEFISH LAKE AREA
LOCATION MAP
ST. PAUL DISTRICT
CORPS OF ENGINEERS


COE-2-19-100
ARROWHEAD LAKE
BIG TROUT LAKE
EXISTING CHANNEL IMPROVEMENT (1960)
PROPOSED CHANNEL IMPROVEMENT
LOWER WHITEFISH LAKE
SCALE

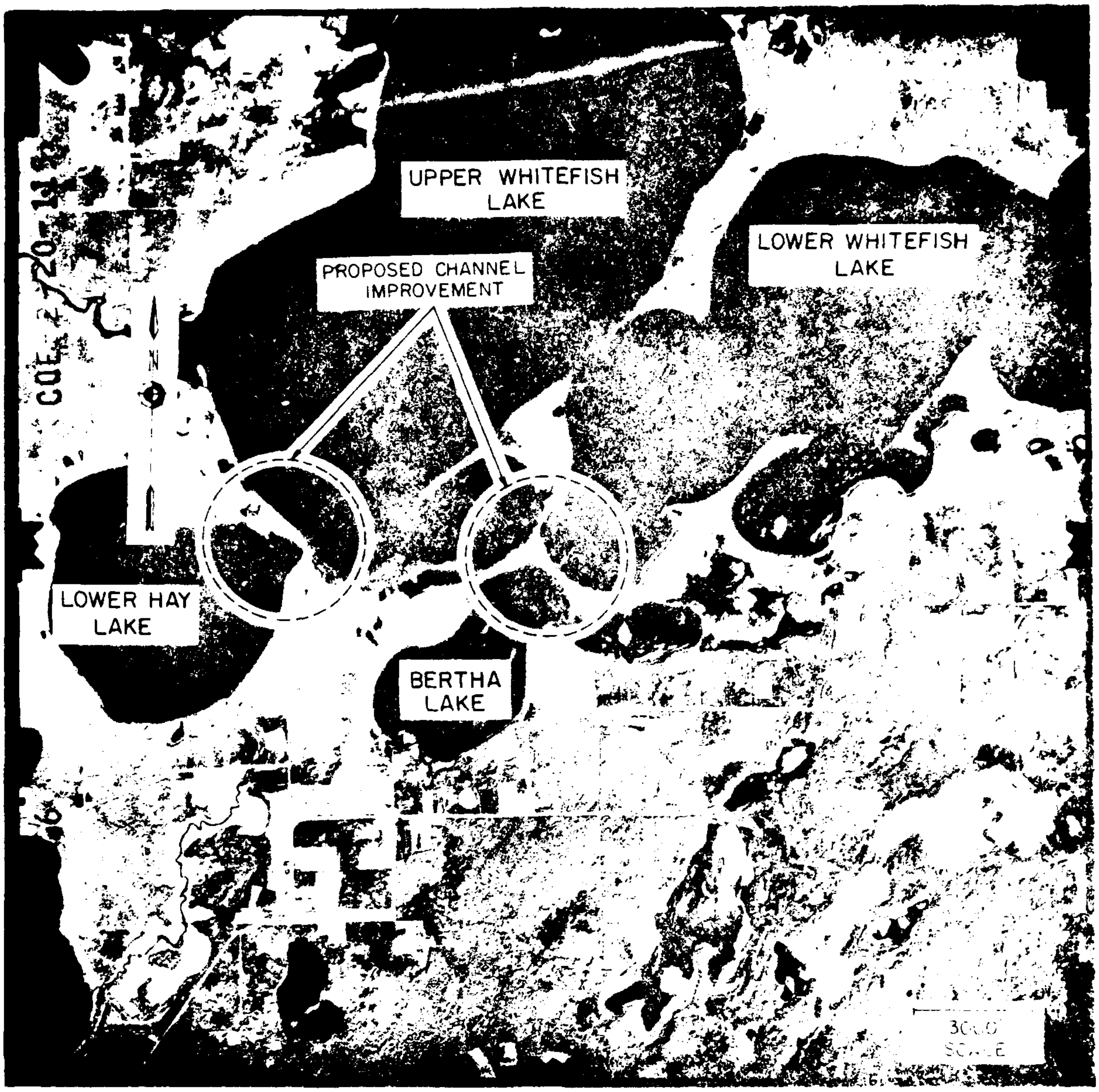
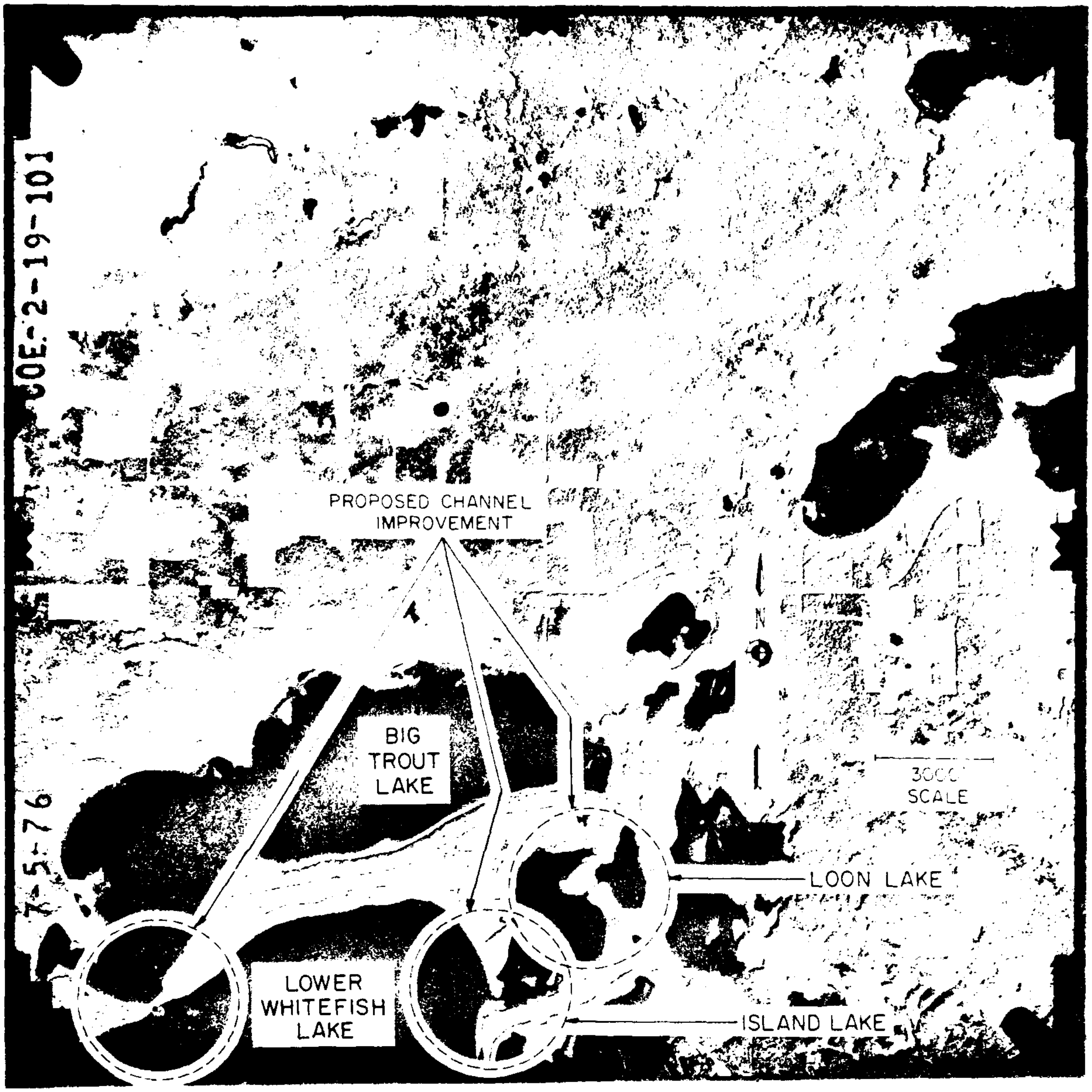

UPPER WHITEFISH
LAKE
LOWER WHITEFISH
LAKE
PROPOSED CHANNEL
IMPROVEMENT
LOWER HAY
LAKE
BERTHA
LAKE
N
SCALE

Plate A-105


COE-2-19-101
7-5-76
PROPOSED CHANNEL
IMPROVEMENT
BIG
TROUT
LAKE
N
SCALE
LOON LAKE
LOWER
WHITEFISH
LAKE
ISLAND LAKE

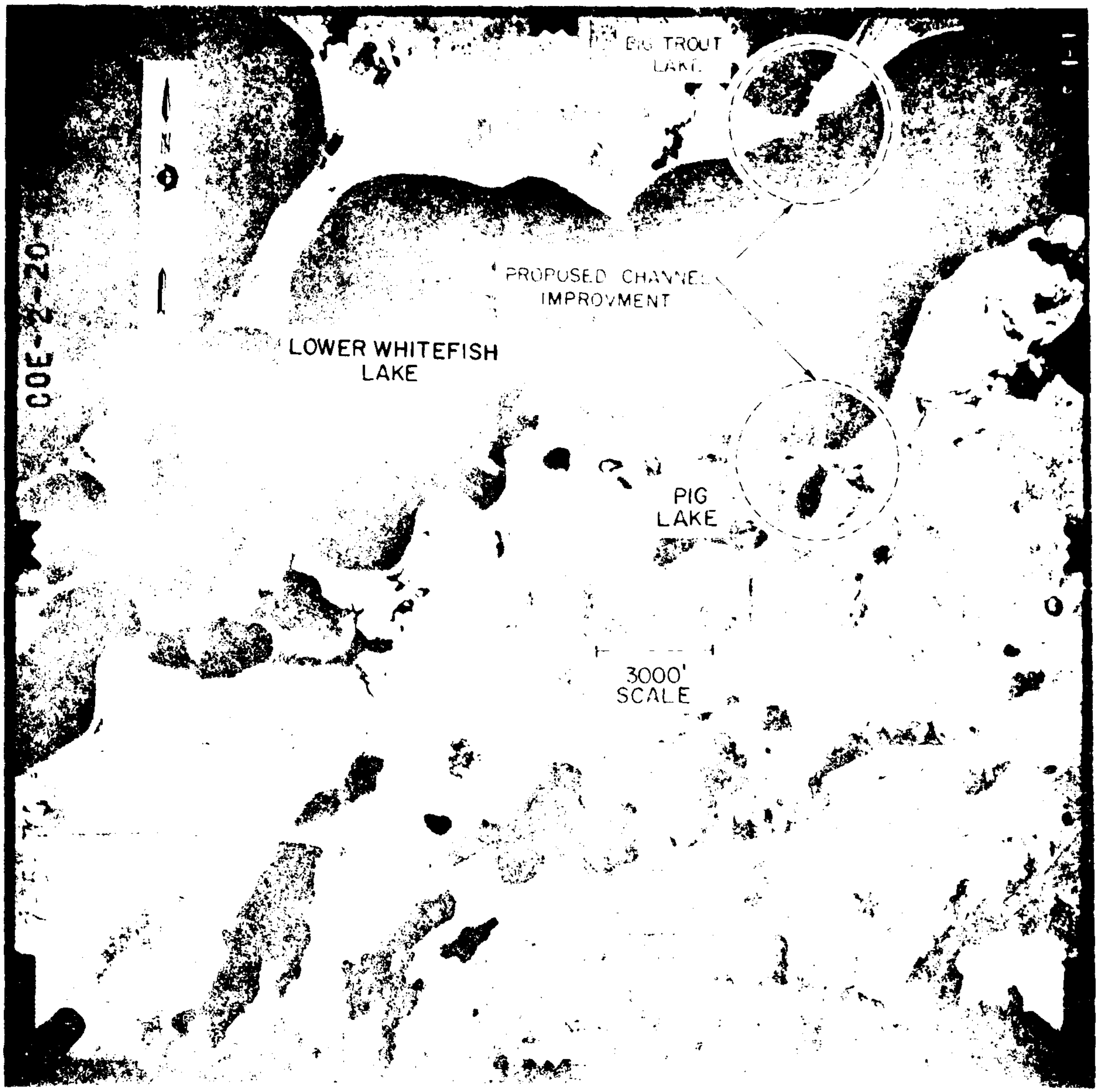
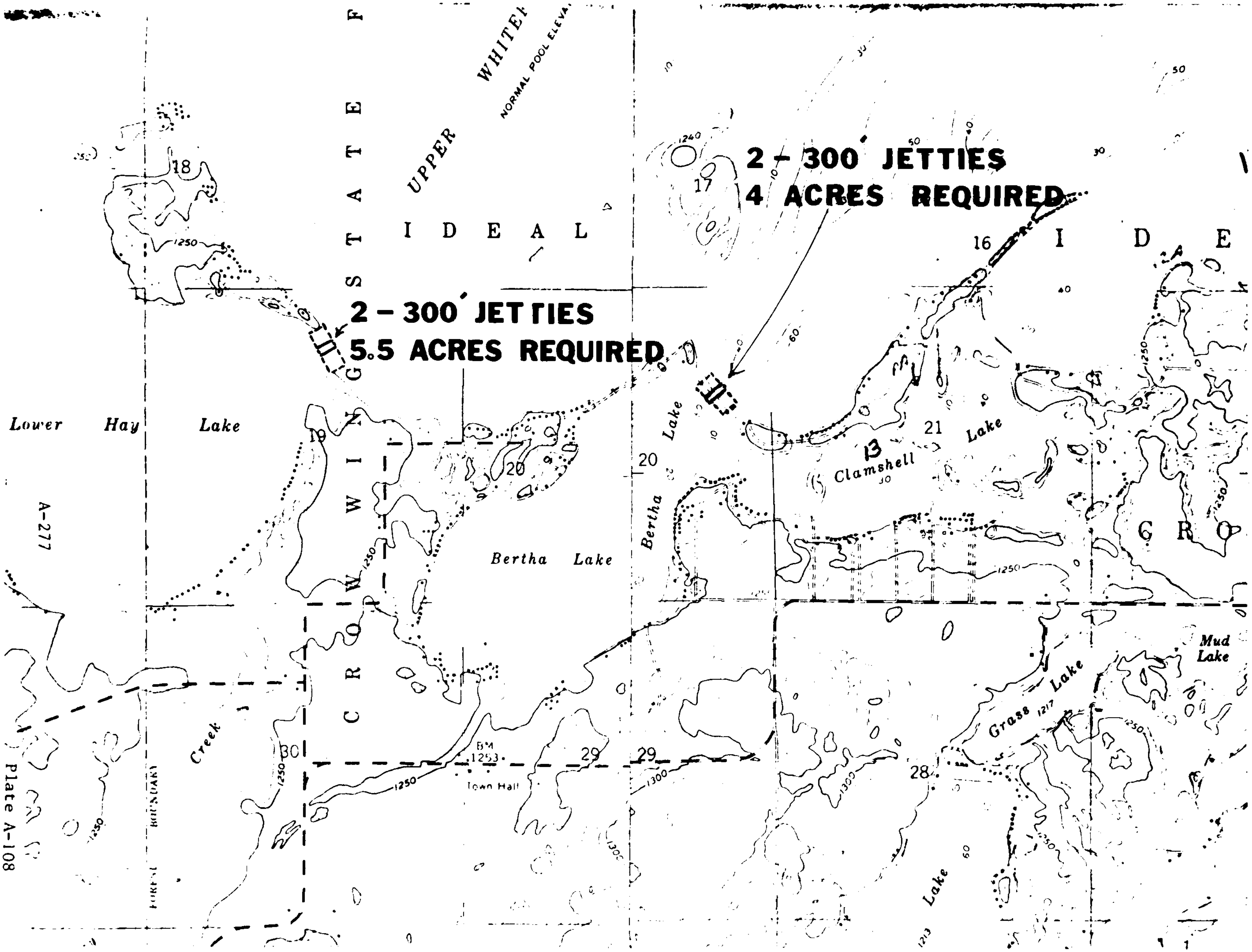
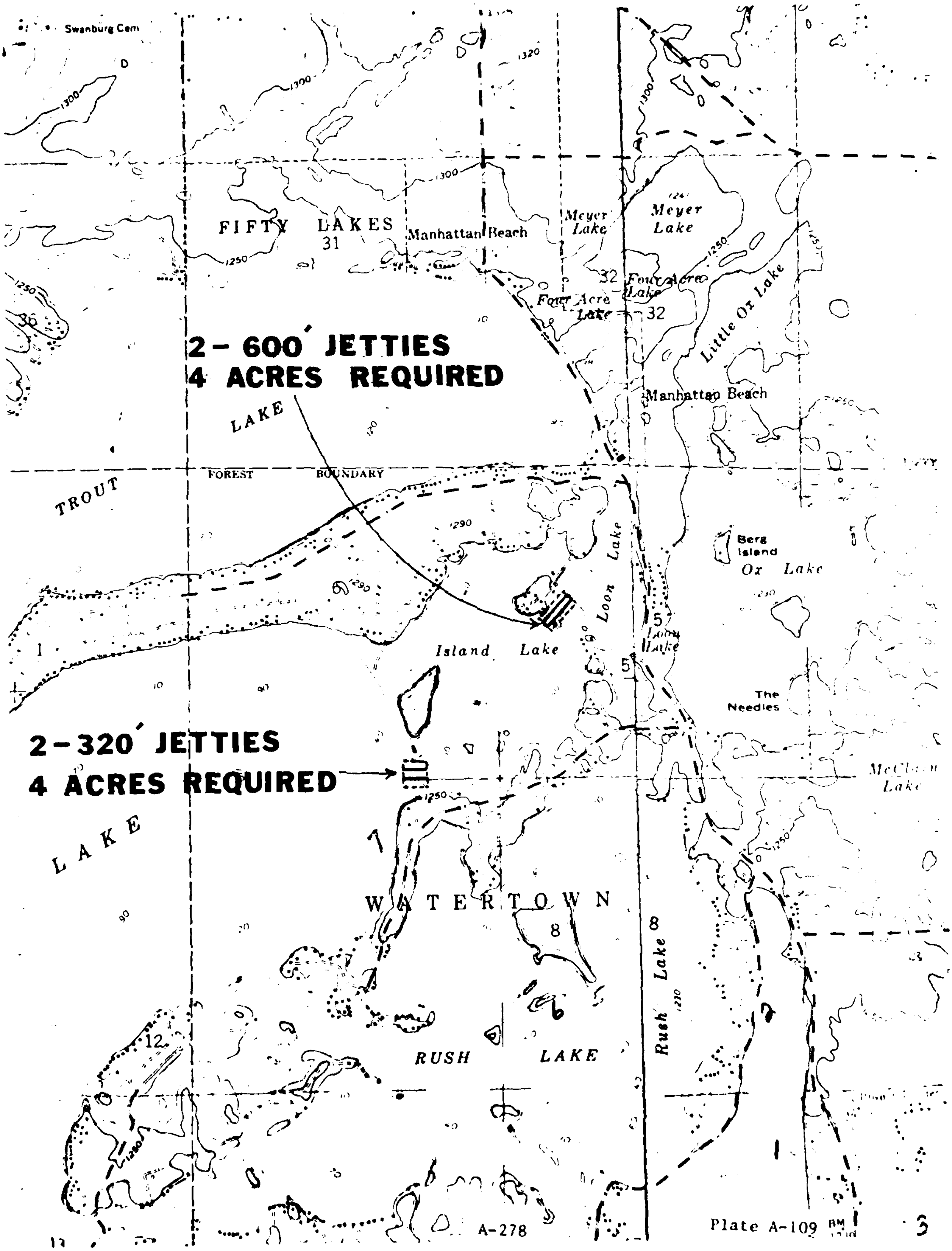

COE-42-20
N
BIG TROUT
LAKE
PROPOSED CHANNEL
IMPROVMENT
LOWER WHITEFISH
LAKE
PIG
LAKE
3000'
SCALE

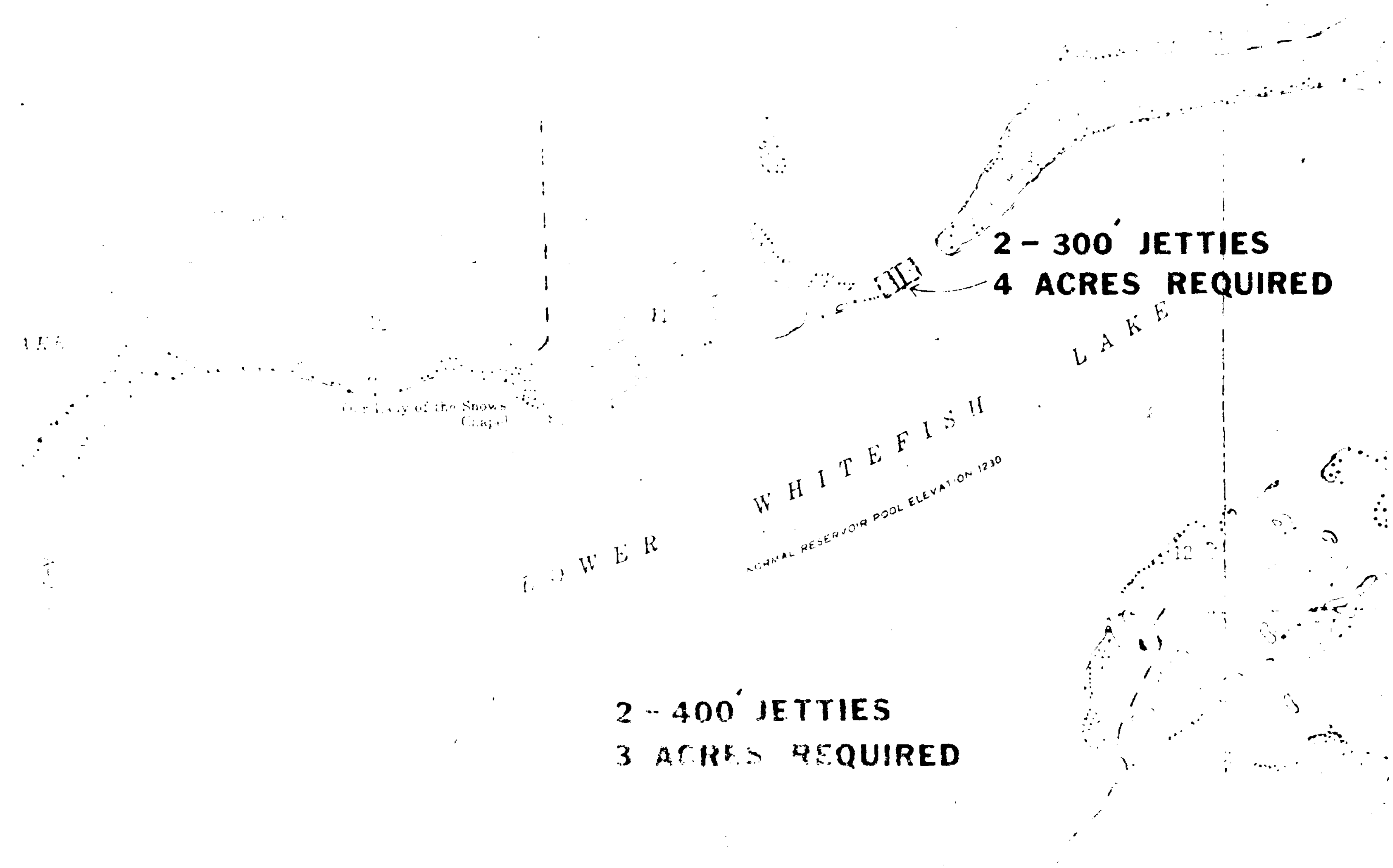
Plate A-107

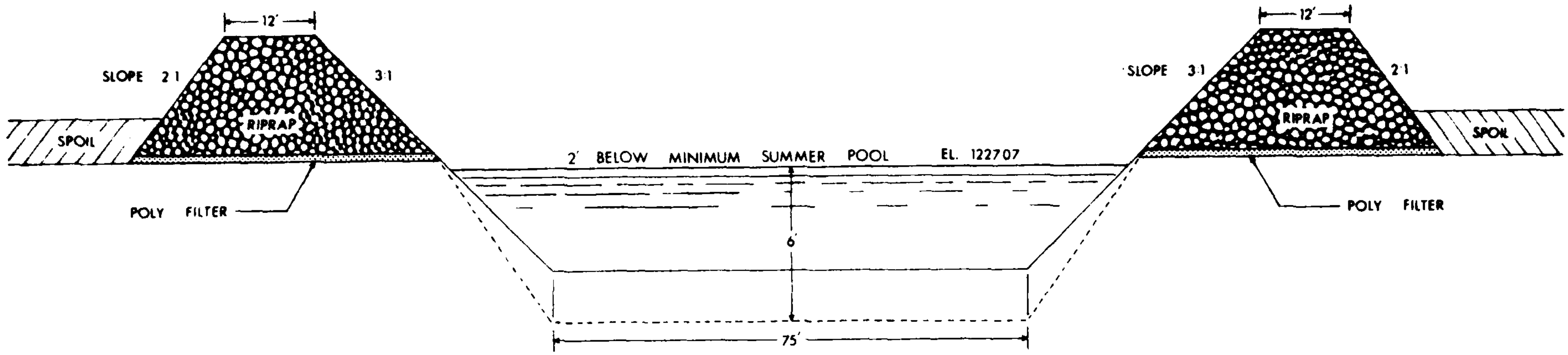


A-277

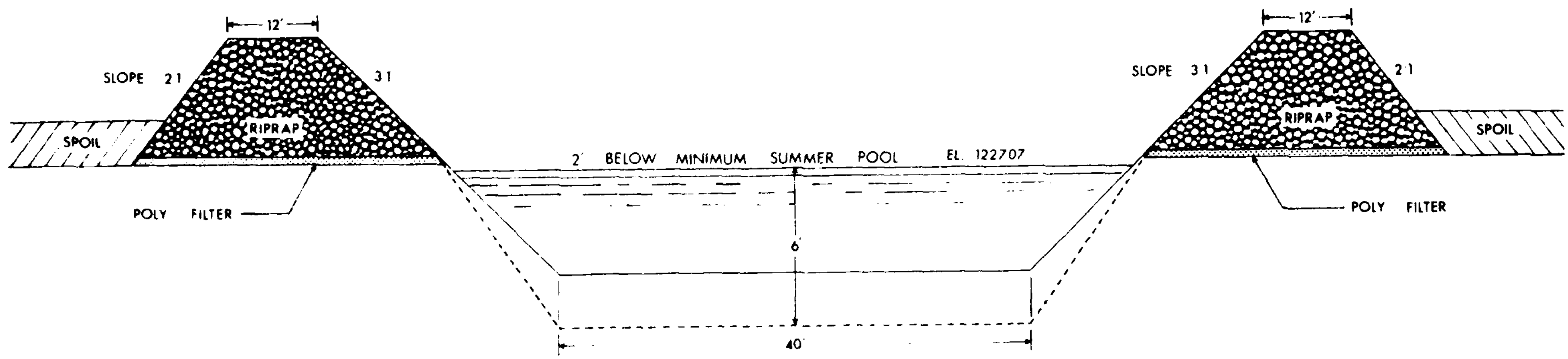
Plate A-108


Swanburg Cem
FIFTY LAKES
31
Manhattan Beach
Meyer Lake
Meyer Lake
Four Acre Lake
Four Acre Lake
32
Little Ox Lake
2 - 600' JETTIES
4 ACRES REQUIRED
Manhattan Beach
LAKE
TROUT
FOREST BOUNDARY
Loon Lake
Berg Island
Ox Lake
Loon Lake
Island Lake
The Needles
2 - 320' JETTIES
4 ACRES REQUIRED
McClain Lake
LAKE
WATERTOWN
8
Rush Lake
RUSH LAKE
12
A-278
Plate A-109


2 - 300' JETTIES
4 ACRES REQUIRED
LOWER WHITEFISH LAKE
NORMAL RESERVOIR POOL ELEVATION 1230
2 - 400' JETTIES
3 ACRES REQUIRED



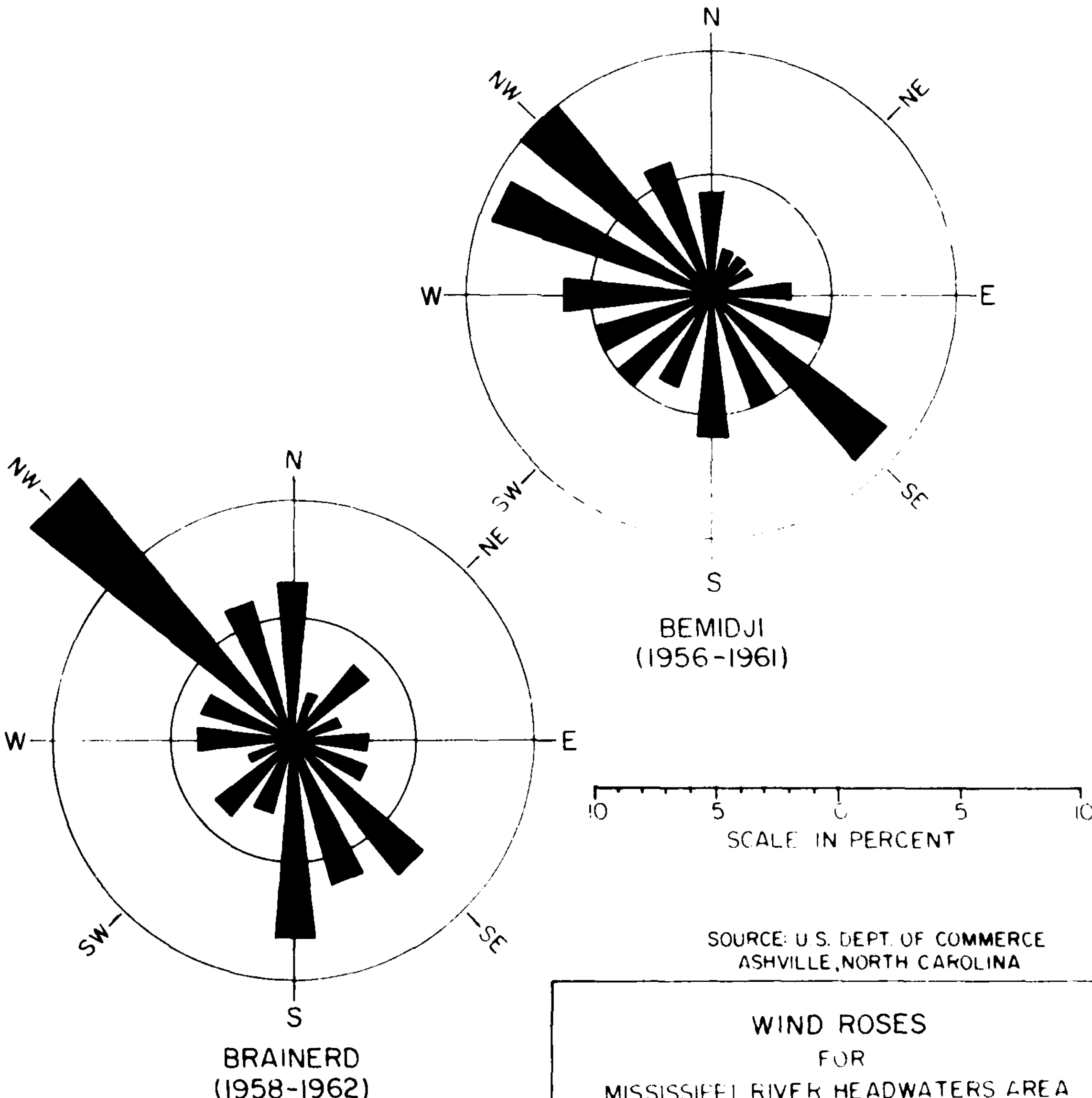
BERTHA LAKE TO WHITEFISH LAKE	300' JETTIES
LOWER HAY LAKE TO WHITEFISH LAKE	300' JETTIES
BIG TROUT LAKE TO WHITEFISH LAKE	300' JETTIES
ISLAND LAKE TO WHITEFISH LAKE	320' JETTIES



EAST BAY OF PIG LAKE TO WHITEFISH LAKE	400' JETTIES
LOON LAKE TO ISLAND LAKE	600' JETTIES

WHITEFISH LAKE
TYPICAL CROSS SECTIONS
AND JETTY CRITERIA
CORPS OF ENGINEERS
ST PAUL DISTRICT

PERCENT OF TIME WIND BLOWS FROM EACH OF
16 MAJOR DIRECTIONS



SOURCE: U.S. DEPT. OF COMMERCE
ASHVILLE, NORTH CAROLINA

WIND ROSES
FOR
MISSISSIPPI RIVER HEADWATERS AREA
MINNESOTA
ST PAUL DISTRICT, CORPS OF ENGINEERS

PROBLEM 8 - LEECH LAKE DAM INLET CHANNEL RESTRICTIONS

BACKGROUND

A physical problem occurs when excess storage is released from Leech Lake at flow rates in the 1,000-cfs range. The problem is most noticeable when the lake is in the 1293.7 to 1294.9 range during prolonged winter drawdowns for flood control (1294.9 is the normal Leech Lake summer level).

Attempts to release 1,000 cfs at the indicated pool levels produce a 0.3- to 1-foot elevation differential between Leech Lake and the Leech Lake Dam, a distance of 9,600 feet. This differential results from (1) the relatively long inlet channel, which is part of the old Leech Lake River, (2) sediment buildup in the inlet channel and at the lake outlet, and (3) weed growth and floating bog.

GEOLOGY AND SOILS

No formal program of subsurface investigation was conducted for this area due to funding constraints. A detailed sampling regime for chemical and total particle size has been recommended. The sampling program would probe the proposed depth of excavation with sample cores taken every 500 feet. The cost of the program is estimated at over $30,000. The information obtained from the program would also provide valuable soils information. Soundings and core samples were taken along a range line in the Leech Lake inlet area in 1912, as shown on plate A-107. These samples showed that the inlet bottom is covered by "muck" from 1 to 7 feet thick and this material is underlain by sand and clay and sometimes quicksand.

HYDROLOGY AND HYDRAULIC STUDIES

District records indicate that the river inlet on the lakeshore to the dam was never dredged. The topography on plates A-108 and A-109 shows natural conditions for 1907, 1912, and 1977. Vegetation growth and sedimentation have effectively raised the general inlet bottom, restricting the lake outflow almost entirely to the present (1977) main channel. However, the present main channel appears more well defined now than in 1912, probably due to the current maintenance practice of removing vegetation and floating bog from the main channel and from the heavy summer use of the channel by recreational craft. A number of outlet bays were eliminated in the Leech Lake Dam over the years of operation, and this has also influenced the channel to become more confined laterally.

Comparing the 1912 and 1977 contours shows that the present channel center line has shifted northeastward, primarily in the reach from cross section 7 to Leech Lake. The 1977 channel center line now lies in what was shoreline in 1912. It appears that this shift in channel was produced in response to lake wave action.

An existing channel roughness or "n" value was developed based on an observed flow of 740 cfs, with 6 inches of ice cover and backwater conditions on 1 December 1977. An improved channel with a 100-foot bottom width, 1 on 4 side slopes, and a slope of 0.000085 would increase the 1 December 1977 channel flow capacity to a desired 1,000 cfs (plate A-110) at 1 foot below normal summer lake elevation 1293.7. The water level at the Leech Lake Dam would be at 1293.4 at this lake elevation and channel flow.

The required channel excavation would be from station 0+00 to 132+00 as shown on plate A-110. The quantities involved are:

Item	Cubic yards
Channel	161,000
Lake shoals at inlet	25,000
Total	186,000

Plate A-107 shows the location of training jetties as proposed in 1913. Training jetties were proposed on each side of a primary inlet channel, which would decrease shoaling and direct lake outflow into the channel inlet leading to Leech Lake Dam. The channel inlet shift since 1912 appears to support the theory that the jetties would work. However, the high cost of jetties and uncertainties about drift direction and quantity of drift make this suggestion impractical for a flow improvement of only 260 cfs.

COST ESTIMATE

The cost estimate shown in the following table is based in part on similar work scheduled for actual construction within the District at Angle Inlet, Lake of the Woods, Minnesota. The dredging would be accomplished with a portable dredge and the dredged material would be pumped to a diked disposal area as shown on plate A-106. The dimensions of the proposed diked disposal area are shown on plate A-111. No maintenance costs are included in the proposal for a 50-year life project as no previous dredging was accomplished in the preceding 94 years.

Detailed estimate of construction costs (1977 prices)

Item	Unit	Quantity	Unit cost	Total cost
First cost				
Construction				
Mobilization and demobilization	Job	Sum	-	$20,000
Dredging	CY	186,000	$3.00	558,000
40-acre disposal area	Job	Sum	-	57,000
Land acquisition	Acre	40	0	0
Total construction cost				635,000
Contingencies				87,000
Engineering and design				77,000
Supervision and administration				77,000
Total first cost				876,000
Average annual costs				
Annualized first cost at 6 5/8 percent interest and 50-year life = 0.06904 x $876,000				60,500
Estimated zero maintenance in 50 years				0
Total average annual costs				60,500
Average annual benefits(1)				143,000
Benefit-cost ratio				2.36

(1) Benefits were derived as described in the following section on benefits.

BENEFITS

Benefits were derived for the proposed Leech Lake inlet proposal by estimating the amount of flood damages prevented on Leech Lake with and without the project. Increasing the Leech Lake inlet winter flow capacity from 740 cfs to 1,000 cfs for a Leech Lake level of 1293.7 would allow an additional 39,000 second-foot days (77,000 acre-feet) to be released in preparation for storing spring high water. The added 260-cfs release over a period of 150 days is equivalent to a 0.6-foot stage reduction in Leech Lake.

The 1930-1976 graphical median high water level on Leech Lake was 1295.5 (plate A-112 for 2.33-year frequency or 43-percent chance of exceedence). Assuming that a 1,000-cfs or greater inlet channel capacity was available during most of the 1936-1976 frequency period, the Leech Lake median high water levels would average 0.6 foot higher at elevation 1296.1. The increased damage from the higher levels is approximately $143,000 (plate A-113). The following table summarizes the costs and benefits for this alternative.

Benefit-cost summary - dredging alternative

Item	1977 prices	1981 prices
First cost	$876,000	$1,173,800
Annual cost (1)	60,500	91,800
Annual benefit	143,000	191,600
Benefit-cost ratio	2.36	2.09
Interest rate	6 5/8	7 5/8

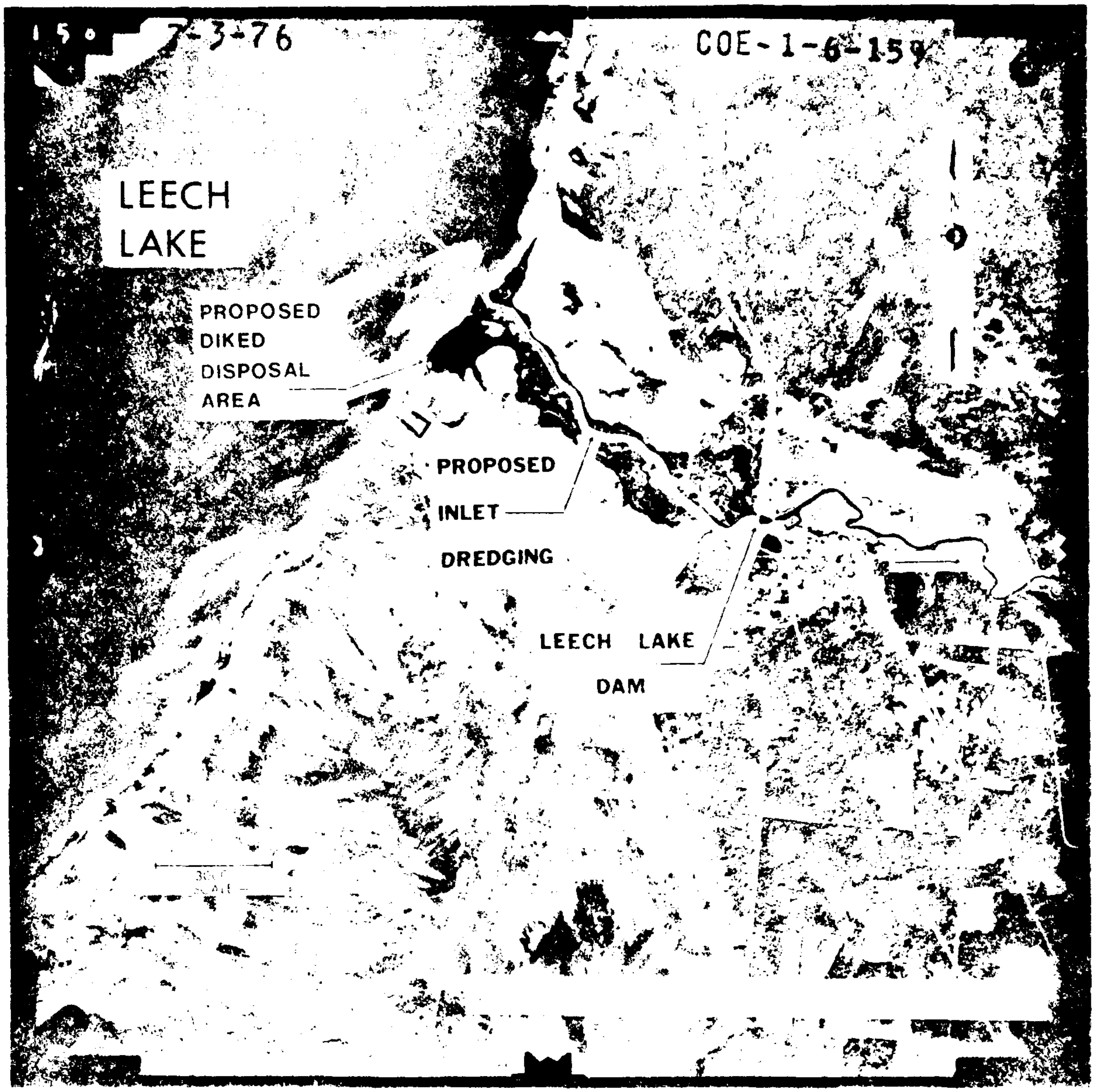
(1) Based on 50-year project life.

RECOMMENDED ACTION

The present Leech Lake inlet channel could be dredged to improve the hydraulic capacity of the Leech Lake Dam. The flow capacity of the dam has been reduced since 1884, when the dam was originally constructed. Shoaling in the vicinity of the Leech Lake entrance creates an obstruction, and removal of about 186,000 cubic yards of material is necessary to provide adequate winter drawdown capabilities. This alternative is not recommended for further investigation in stage 3 studies but is recommended for funding in fiscal year 1981 under the St. Paul District's regular scheduled maintenance program.

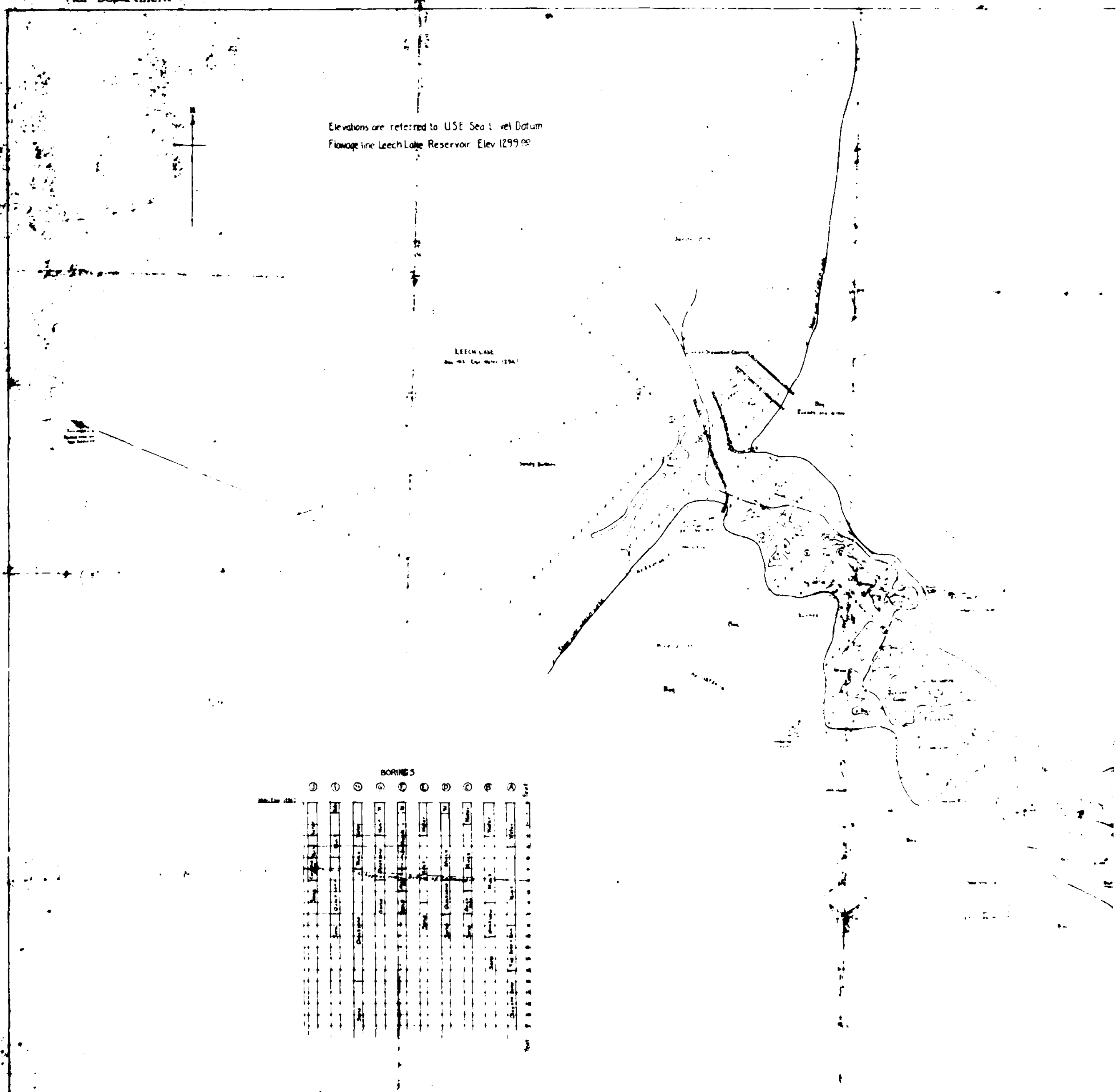
PLATE SUMMARY

Number	Item
A-113	Leech Lake Dam inlet channel restrictions
A-114	Alternative channels (1913)
A-115	1977 survey
A-116	Channel center line and elevations
A-117	Profile of proposed channel dredging
A-118	Leech Lake inlet disposal area
A-119	Elevation-frequency analysis
A-120	Elevation-damage curve

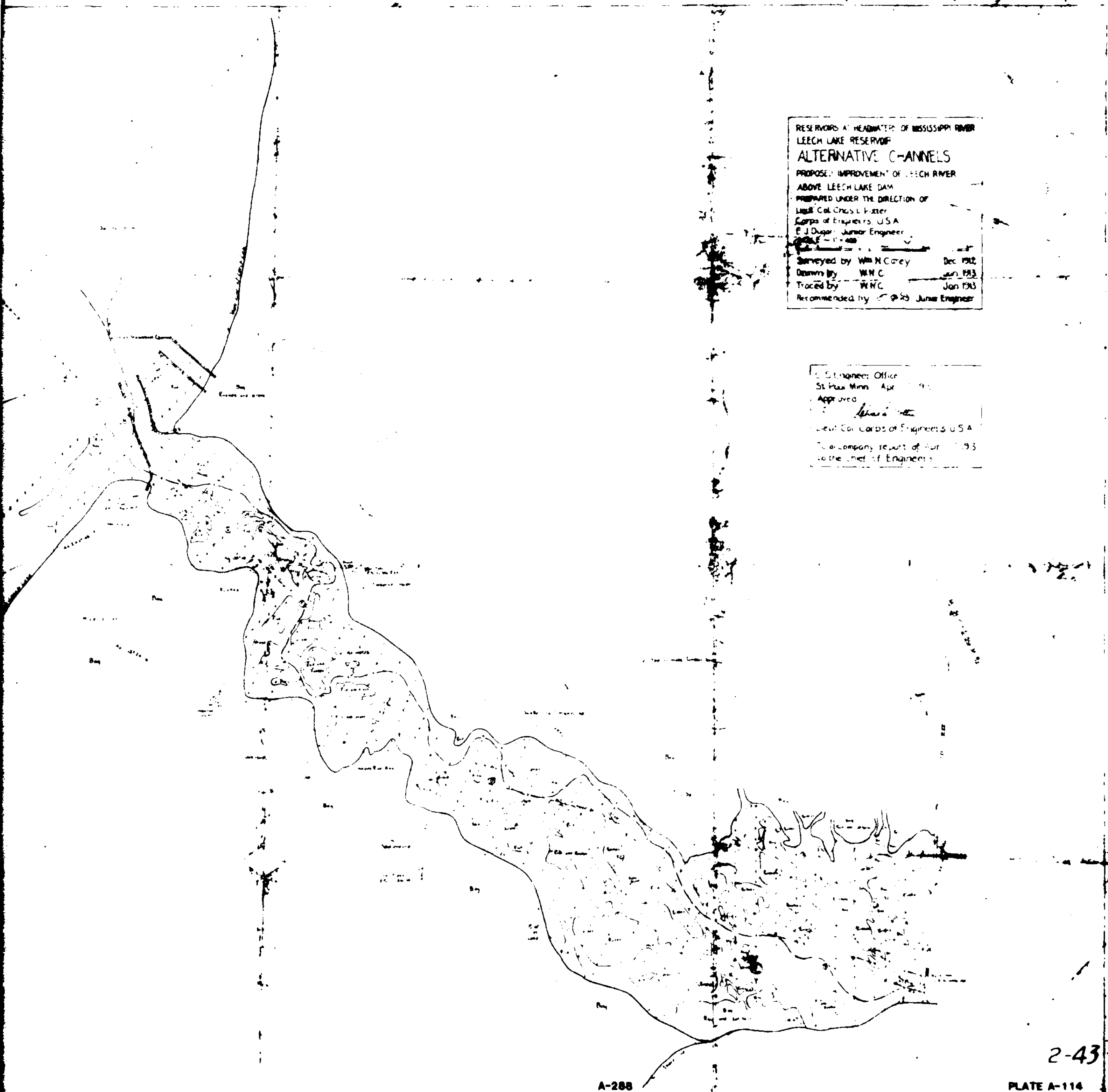


7-3-76
COE-1-6-159
LEECH LAKE
PROPOSED
DIKED
DISPOSAL
AREA
PROPOSED
INLET
DREDGING
LEECH LAKE
DAM

War Department



Corps of Engineers, U S Army

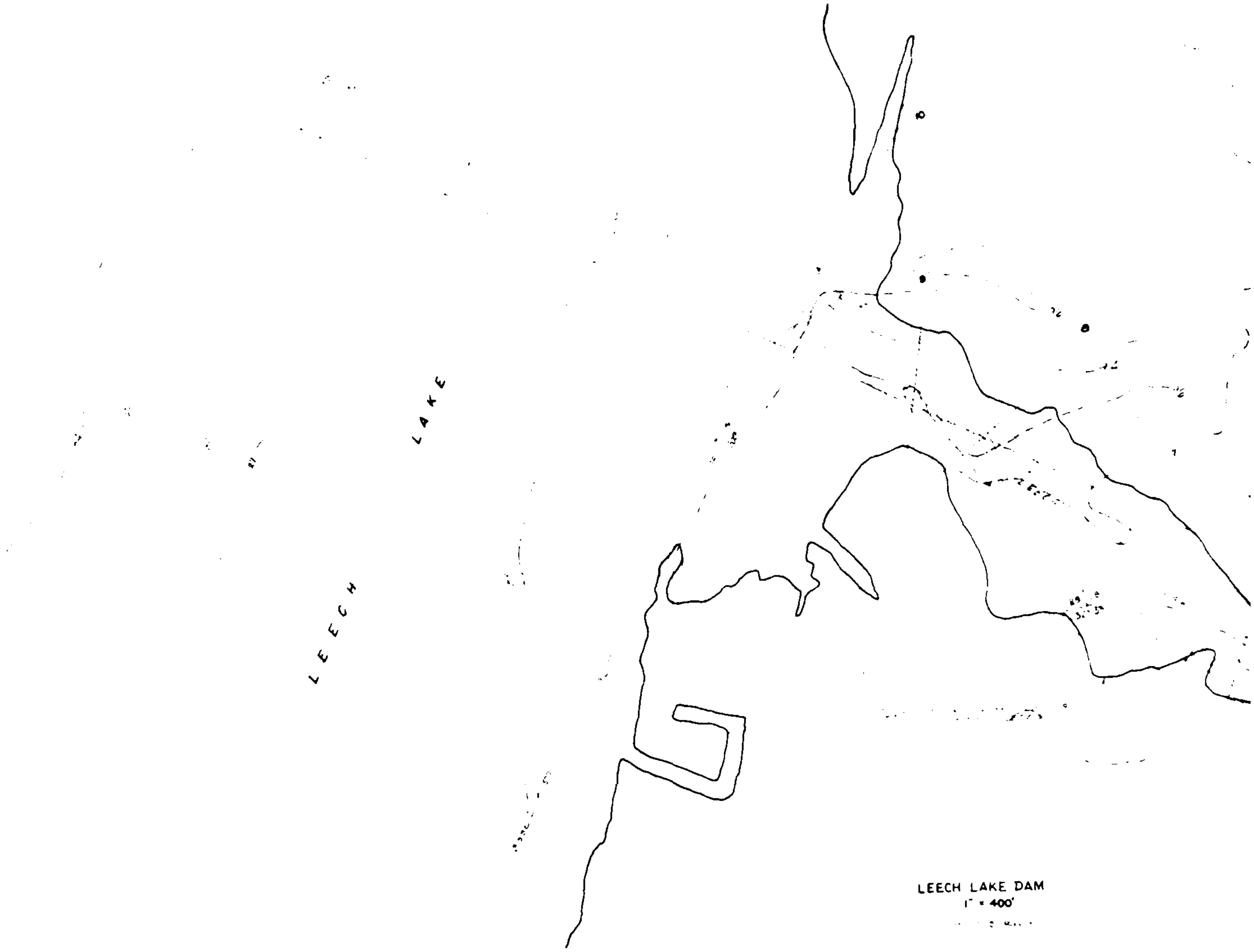


2-43

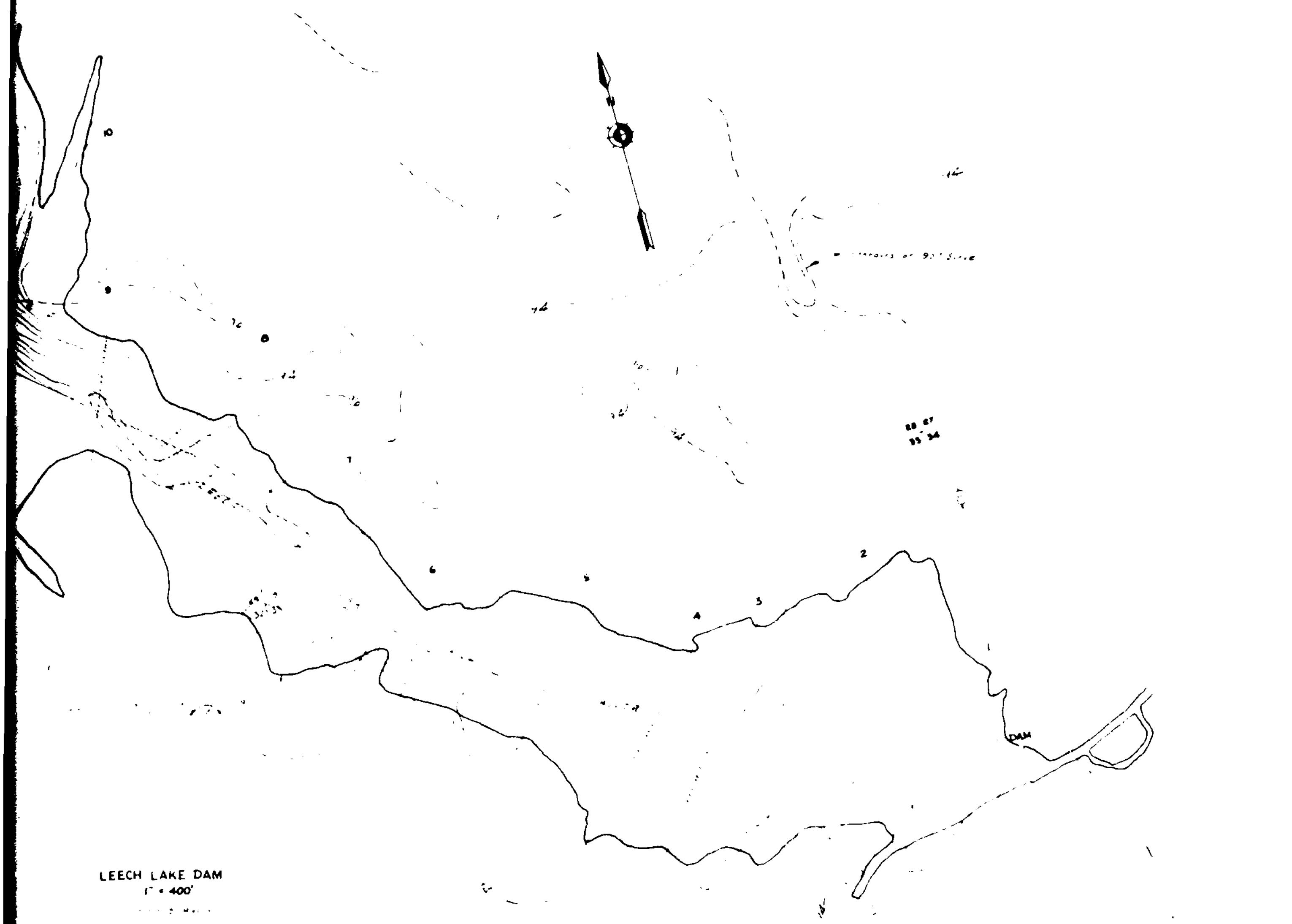
A-288

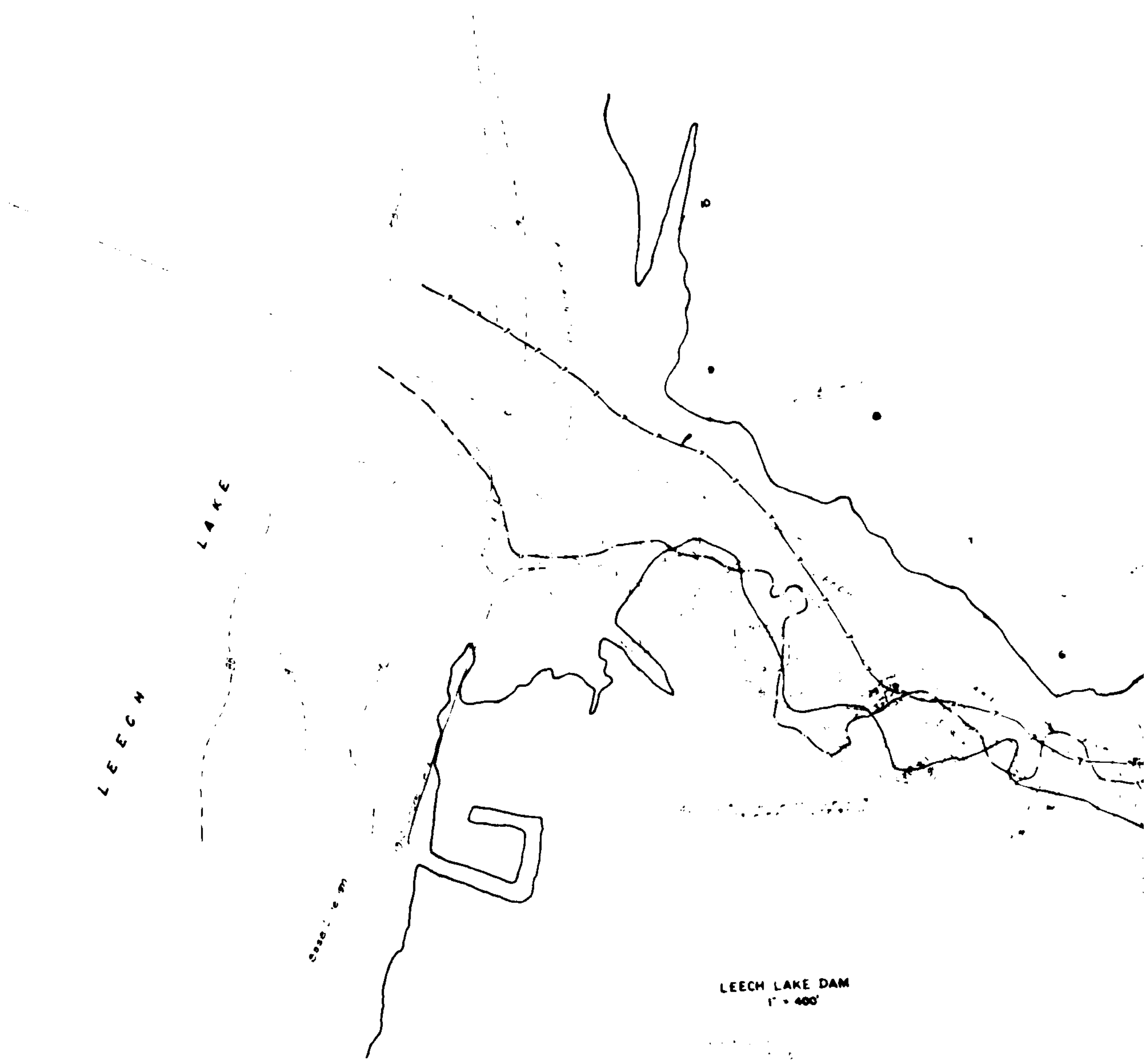
PLATE A-114

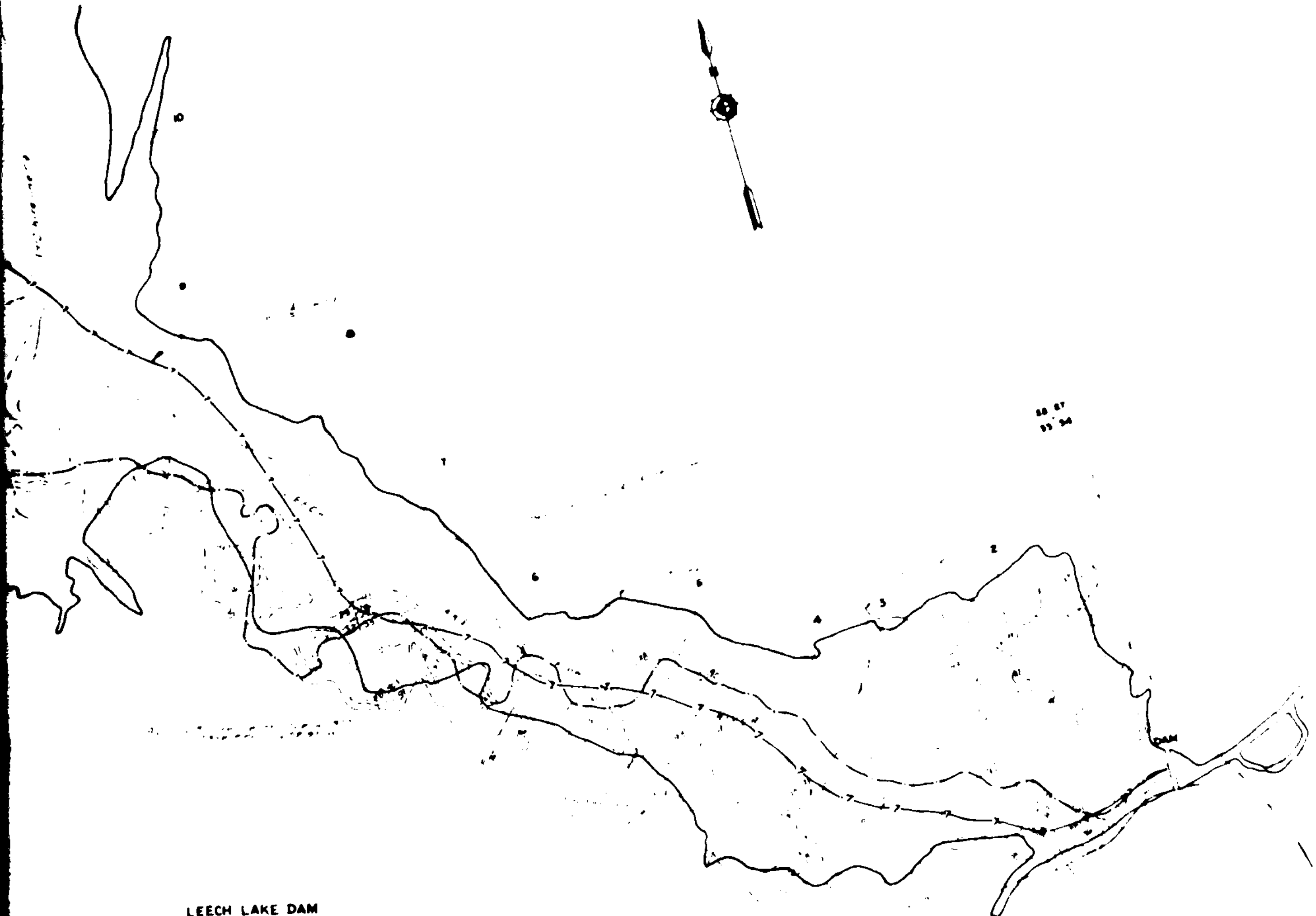
Channels Above Leech Lake Dam



LEECH LAKE DAM
1" = 400'


LEECH LAKE DAM
1" = 400'
DAM
MISSISSIPPI RIVER HEADWATERS STUDY
LEECH LAKE INLET CHANNEL
1977 SURVEY
ST PAUL DISTRICT CORPS OF ENGINEERS
PLATE A-115


LEECH LAKE
LEECH LAKE DAM
1" = 400'



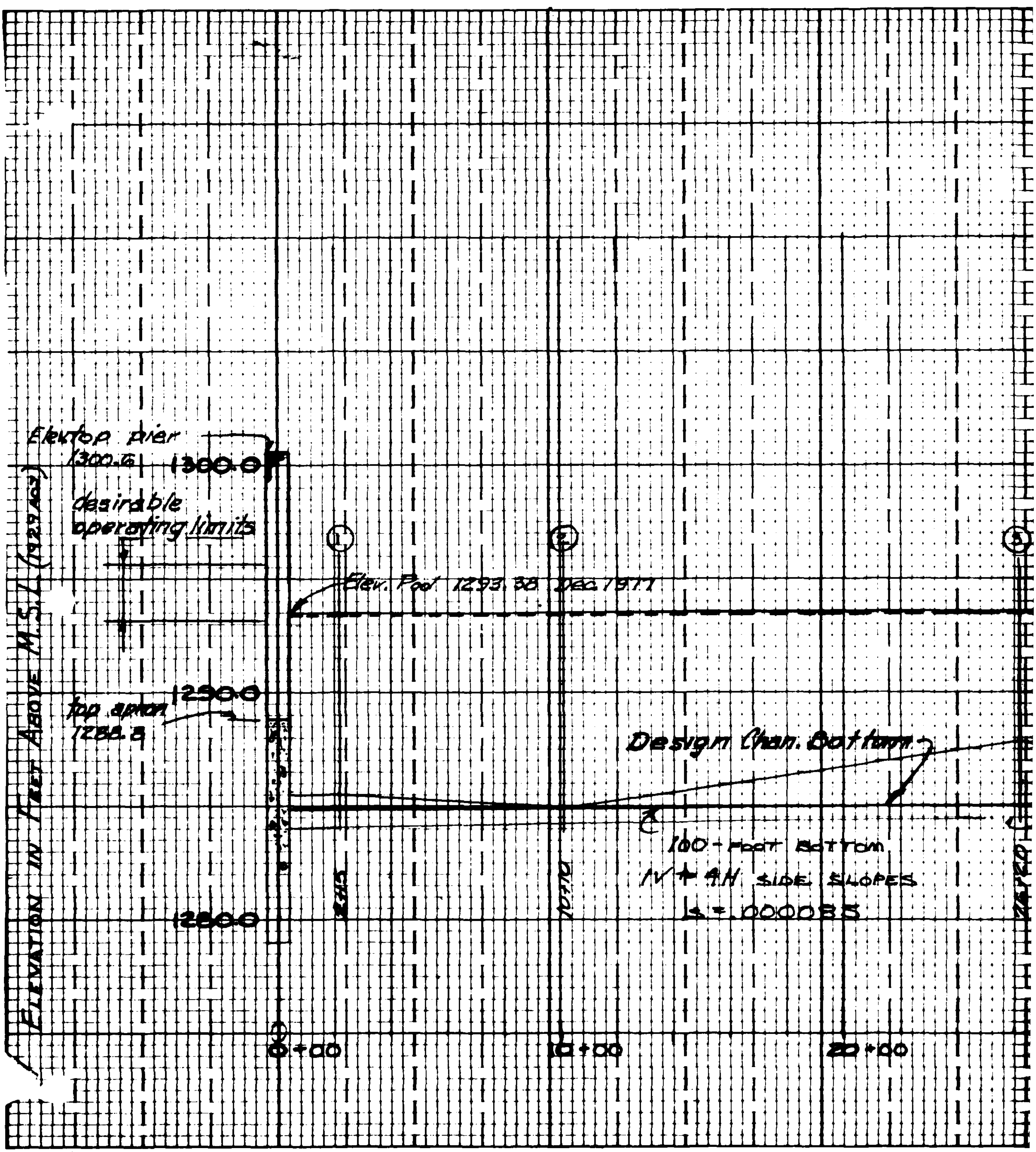
MISSISSIPPI RIVER HEADWATERS STUDY

LEECH LAKE INLET CHANNEL

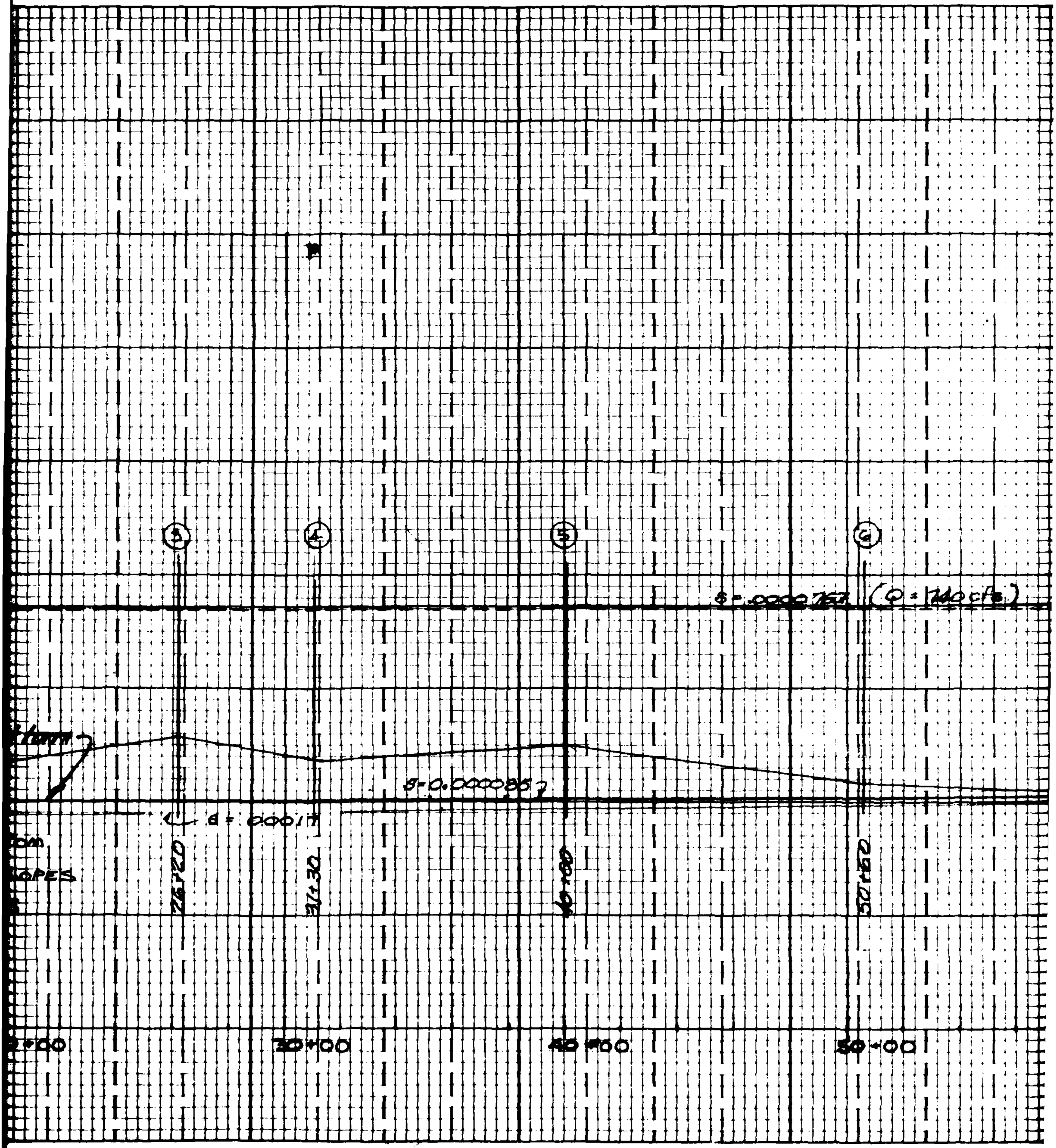
channel centerline

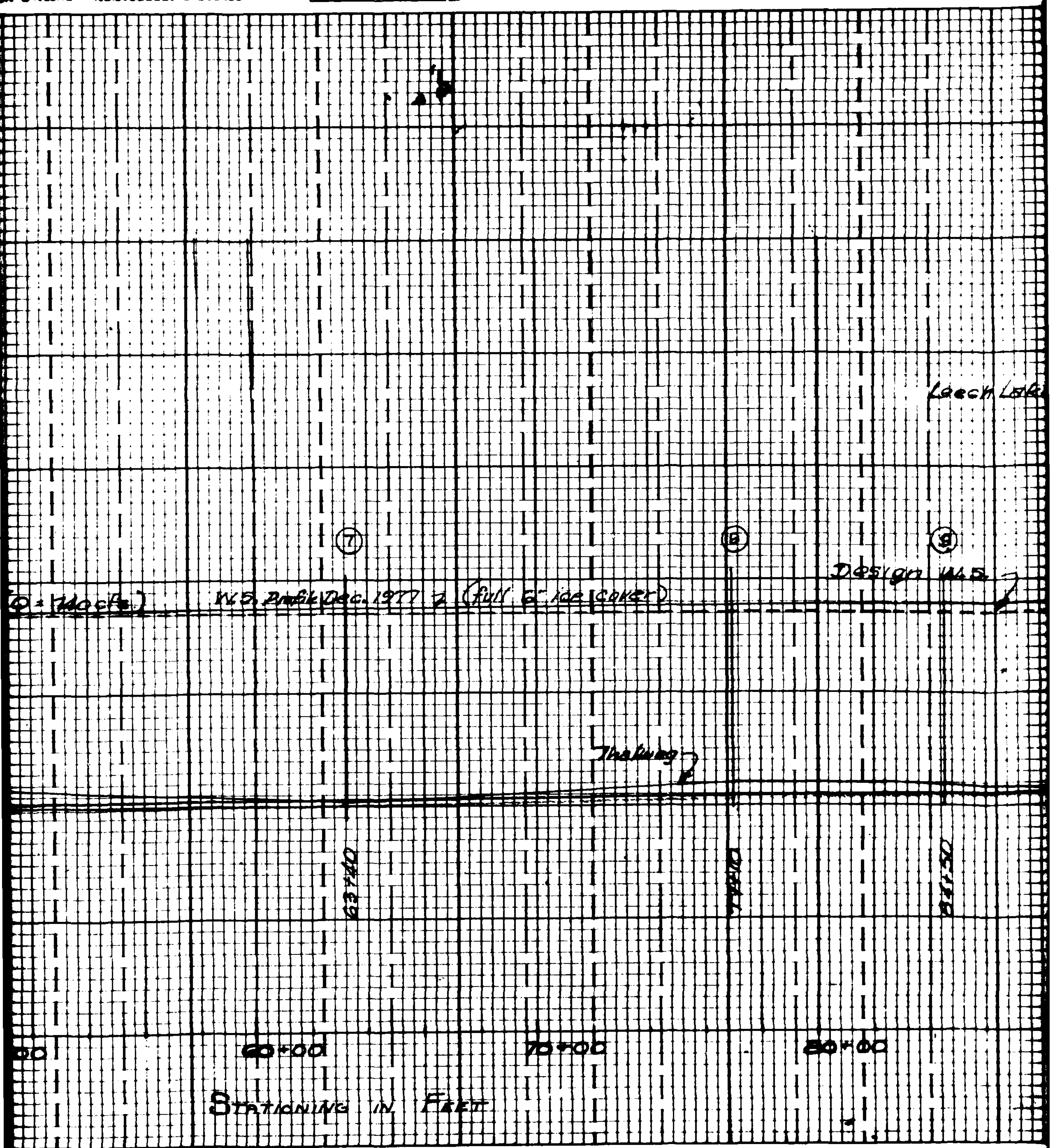
and elevations

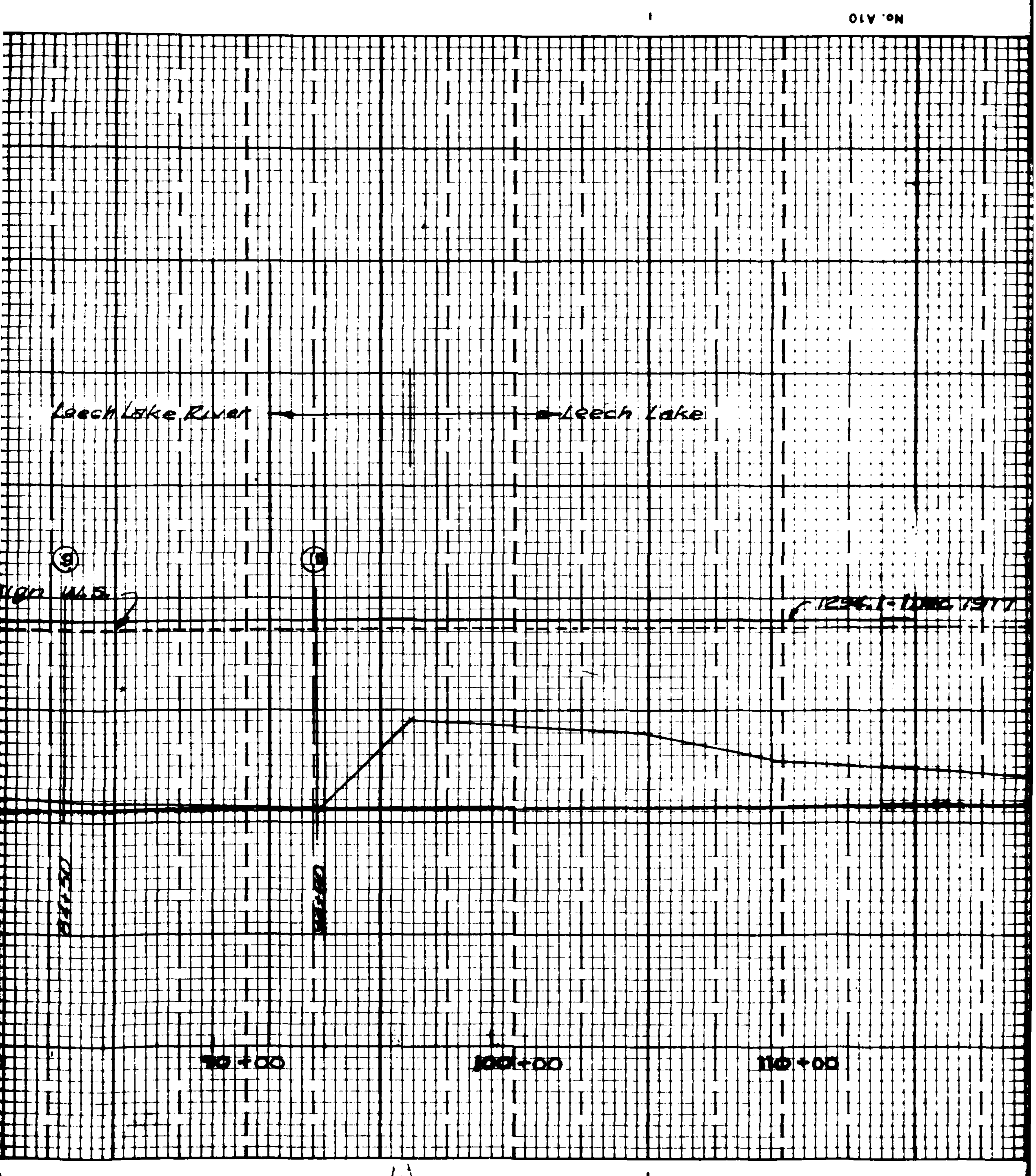
ST PAUL DISTRICT CORPS OF ENGINEERS



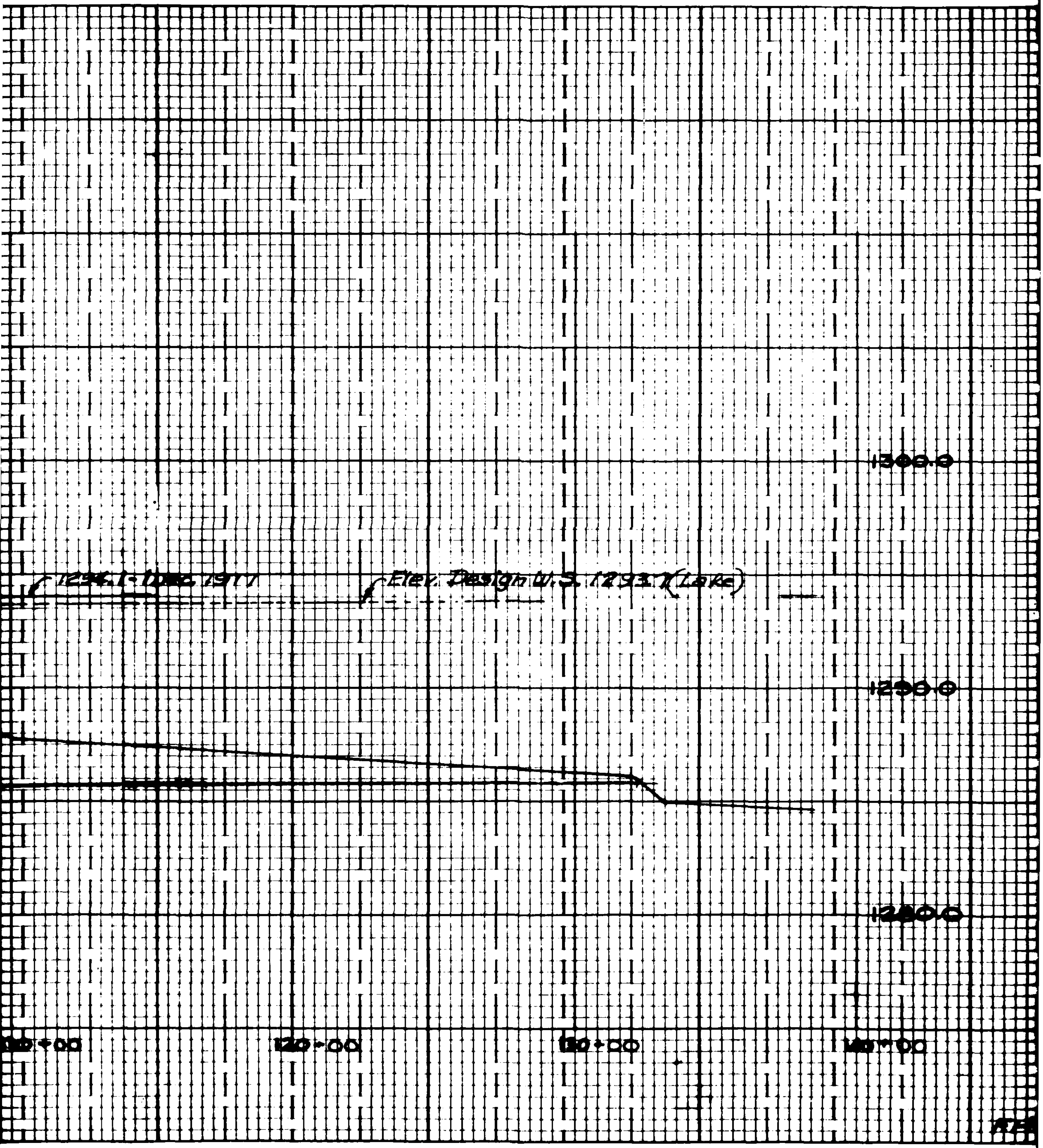
Elev.top pier
1300.6
1300.0
desirable
operating limits
Elev. Pool 1293.38 Dec. 1977
1290.0
top apron
1288.8
Design Chan. Bottom
100-FOOT BOTTOM
1V + 4H SIDE SLOPES
S = .000085
1280.0
0+00
10+00
20+00
ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ)


3
4
5
6
S = .0000767 (Q = 740 cfs)
S = 0.000086
S = .00017
26+20
31+30
40+00
50+00
30+00
40+00
50+00


Leech Lake
7
8
9
Design W.S.
Q = 140 cfs
W.S. Profile Dec. 1977 (full 6" ice cover)
Thalweg
63+40
84+50
60+00
70+00
80+00
Stationing in Feet



NO. A10
Leech Lake River
Leech Lake
ign W.S.
90+00
100+00
110+00



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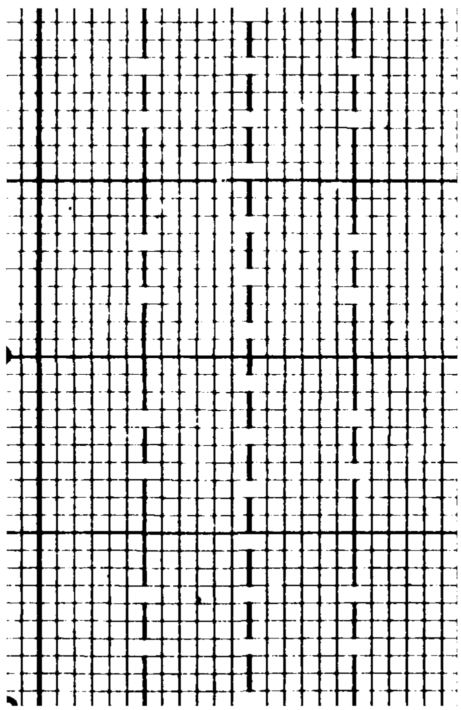
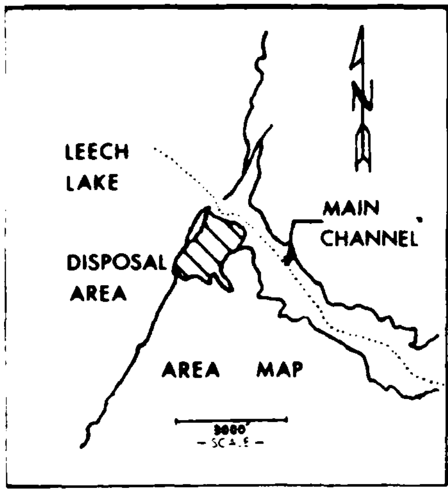
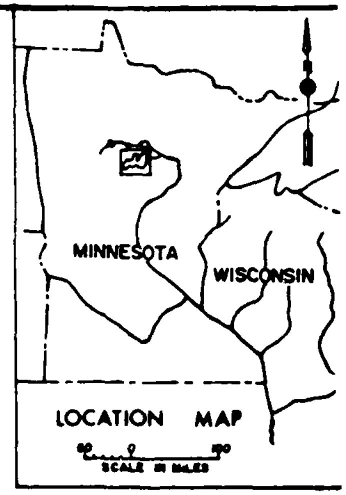
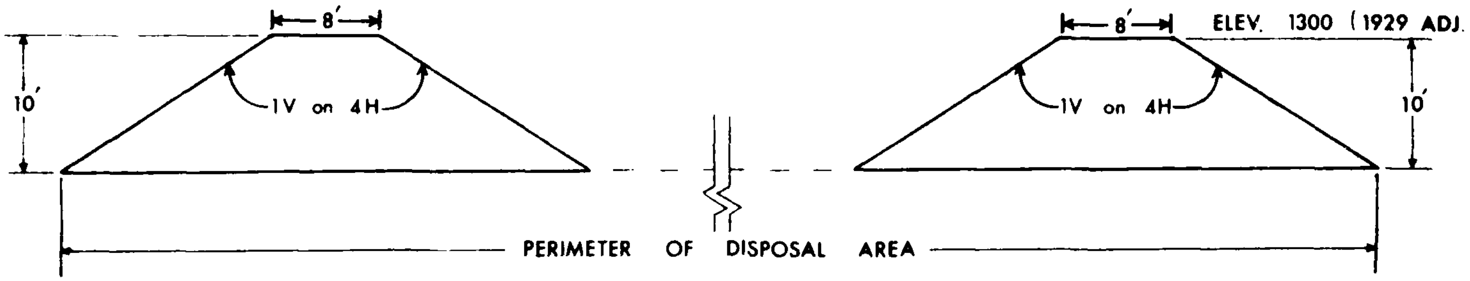


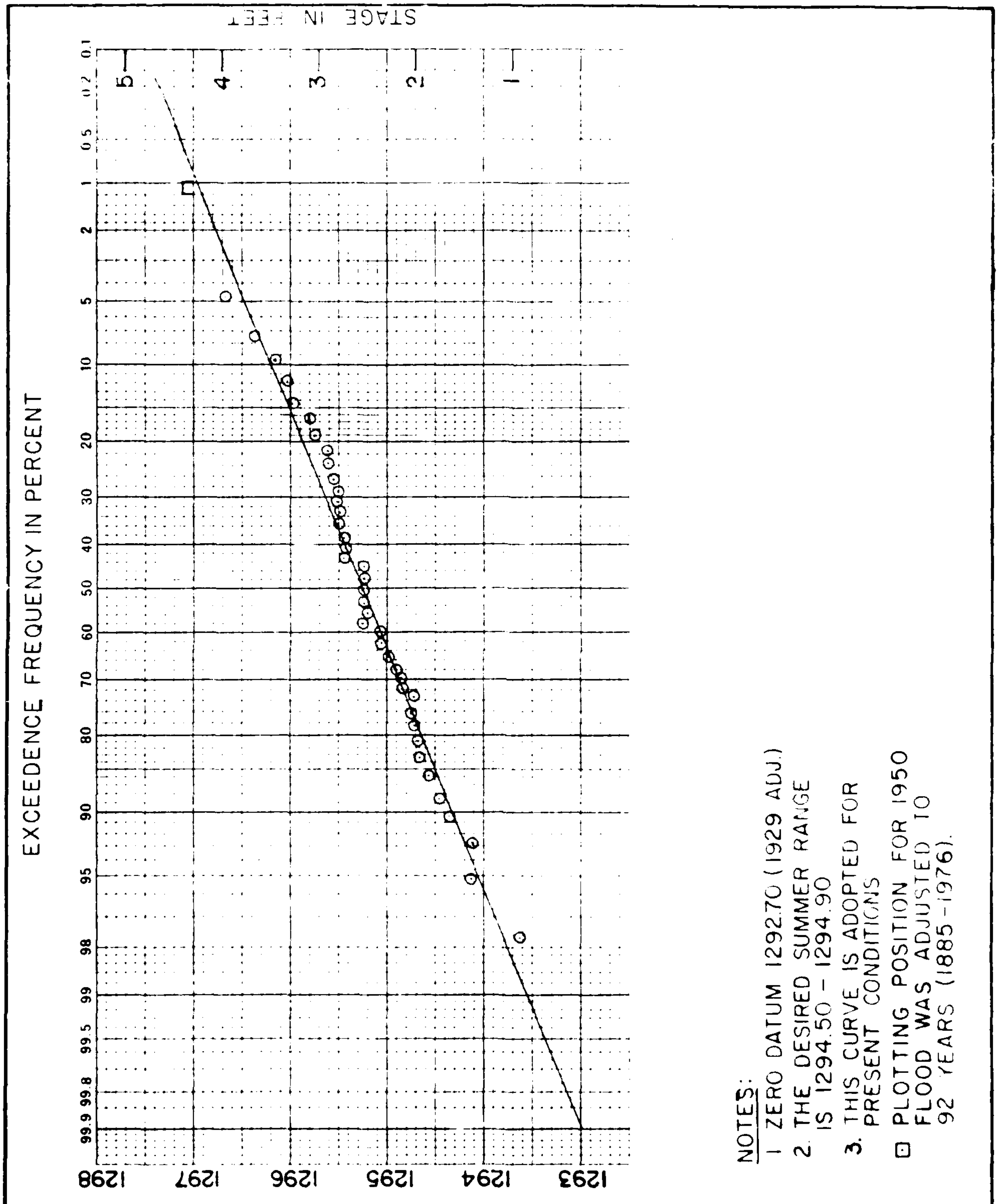






DISPOSAL AREA SECTION
— NO SCALE —

LEECH LAKE INLET
DISPOSAL AREA
ST. PAUL DISTRICT
CORPS OF ENGINEERS

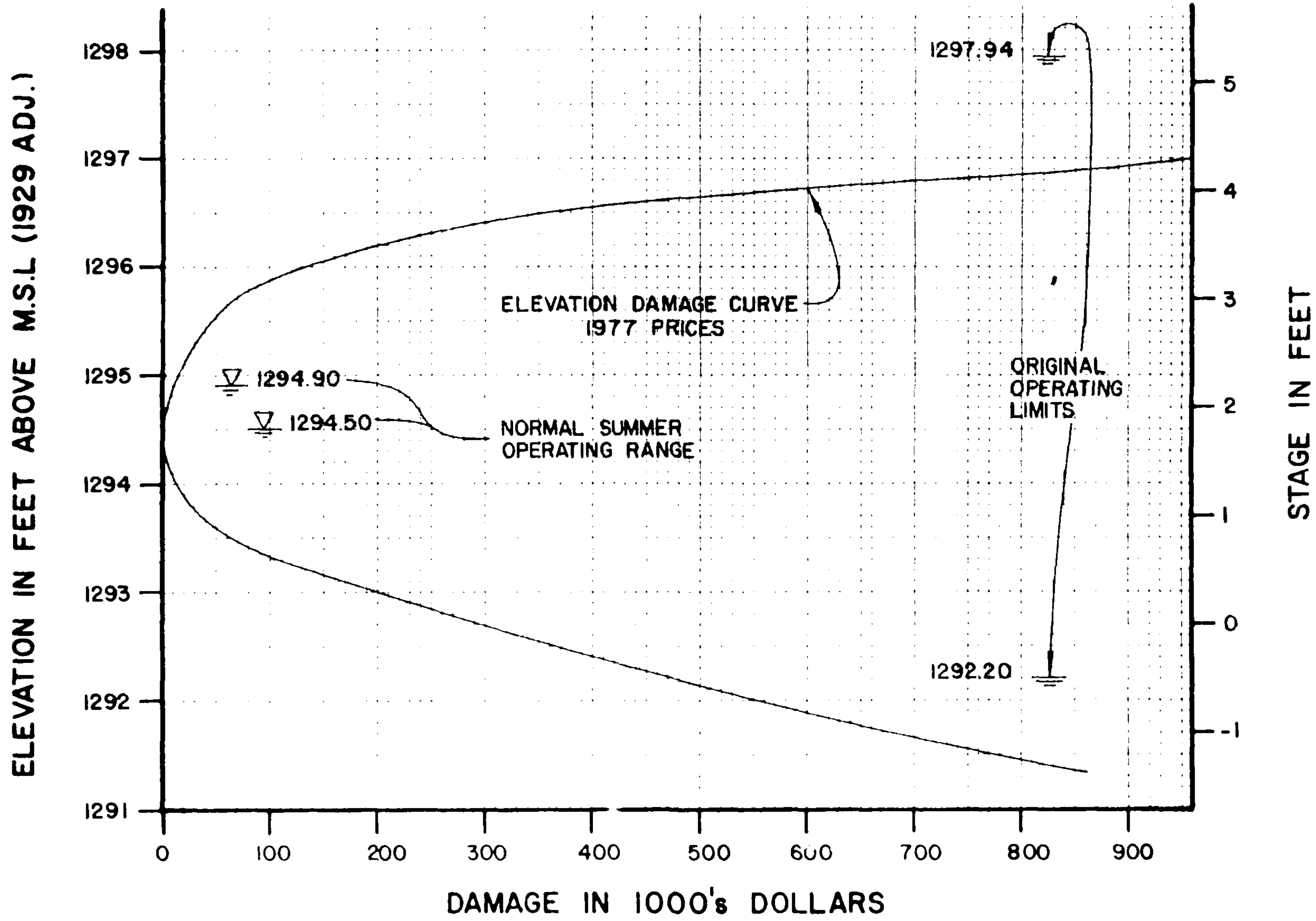


MISSISSIPPI RIVER HEADWATERS STUDY
STAGE – FREQUENCY ANALYSIS

LEECH LAKE
1936 - 1976

ST. PAUL DISTRICT CORPS OF ENGINEERS

LEECH LAKE
ELEVATION DAMAGE CURVE



APRIL 1978

PROBLEM 9 - LEECH LAKE MARSH CHANNEL CUTOFFS

BACKGROUND

The Corps of Engineers completed channel improvement including straightening and closing of auxiliary channels in the areas below Leech Lake and Winnibigoshish Dams during the period 1914 to 1926. This construction was accomplished to provide more efficient flow of water to Pokegama Lake Dam and for downstream navigation below Minneapolis. The improved channel depths resulting from this straightening provided some benefits to the movement of logs on the Leech Lake and Mississippi Rivers. Wild rice production and fish and wildlife resources were lost because of the channel work. Several dikes on the Leech Lake River upstream of Mud Lake could restore some of the habitat lost to channel straightening.

GEOLOGY AND SOILS

No formal program of subsurface investigations was conducted for this area as the preliminary analysis of possible diking of Leech Lake Marsh cutoffs did not show economic feasibility.

HYDROLOGY AND HYDRAULIC STUDIES

The proposed plan of improvement was first proposed in 1966 and is shown on plate A-114. Approximately 1,300 acres of dry marsh area would be inundated with an average depth of 3 feet of water by restoring and raising existing dredged material disposal banks along the Leech Lake River downstream from Leech Lake Dam. The existing dredged material banks were the result of channel straightening efforts by the St. Paul District during the period 1914 to 1926.

The area proposed for development would consist of the 4-mile reach of the Leech Lake River downstream of Leech Lake Dam. Water would be released from Leech Lake Dam through a new control structure and could be supplied to four diked pools along the Leech Lake River by means of control culverts and inverted siphons. The inverted siphons would be necessary to carry flows across the Leech Lake River in two places.

Average dike heights would be 8 feet and pool depths would be 18 to 36 inches for growing wild rice. All control structures were sized to provide 18 inches of water depth for all pool areas within 30 days. Planimetered pool acreages from plate A-114 are as follows:

Pool	Area (acres)
1	80
2	280
3	540
4	420
Total	1,320

The above pool acreages were adjusted to account for private wild rice paddy developments which have occurred in the area since the project was proposed in 1966 (see plate A-115). The private development of wild rice has reduced the proposed pool 3 area by 50 percent, leaving only about 270 undeveloped acres of the originally proposed 540 acres. The resulting proposal would provide 1,050 surface acres for wild rice and fish and wildlife habitat if constructed today.

COST ESTIMATE

The total first cost of this project would be $1,276,900. An annualized first cost, plus $5,000 for annual operation and maintenance, results in a total annual cost of $93,200 at 6 5/8-percent interest and a 50-year project life. Annual benefits are $53,250, resulting in an unfavorable benefit-cost ratio of 0.57. The following table is a detailed cost estimate for this proposal; however, the project is not feasible.

Detailed estimate of construction costs

Item	Unit	Quantity	Unit cost	Total cost
				(1977 prices)
First cost				
Construction				
Grade and shape existing dikes	CY	52,500	$1.00	$52,500
Construct new dikes	CY	247,500	1.50	371,200
Stripping for new dikes	CY	33,000	0.55	18,100
Access road (pool 2-4)	Job	Sum	-	13,600
Access road on dikes	Job	Sum	-	246,200
36-inch RCP water control, Leech Lake pool	Job	Sum	-	14,800
36-inch RCP water control, pool 1-2	Job	Sum	-	7,100
36-inch RCP water control, pool 2 to river	Job	Sum	-	13,700
30-inch steel, inverted siphon, pool 2 to 3	Job	Sum	-	30,900
42-inch RCP water control, pool 3 to river	Job	Sum	-	14,300
24-inch steel inverted siphon, pool 3-4	Job	Sum	-	27,300
42-inch RCP water control, pool 4 to river	Job	Sum	-	14,300
Total construction cost				824,000
Lands	Acre	2,025	50.00	101,250
Contingencies				185,050
Engineering and design				83,300
Supervision and administration				83,300
Total first cost				1,276,900
Annual cost				
Annualized first cost (1)				88,200
Annual operation and maintenance				5,000
Total annual cost				93,200

(1) 6 5/8-percent interest and 50-year project life.

BENEFITS

Benefits were determined from the following values supplied by the State of Minnesota for a proposed subimpoundment development elsewhere on Leech Lake.

Item	October 1977 value per acre
Wild rice	$22.33
Waterfowl	20.35
Muskrats	3.95
Mink	1.28
Pike spawning	2.80
Total	50.71

$50.71 x 1,050 acres = $53,250

The summary benefit-cost analysis for this proposed development is:

$$\text{Benefit-cost ratio} - \frac{\$53,250}{\$93,200} = 0.57$$

The following table summarizes the benefits and costs for the alternative.

Benefit-cost summary - Leech Lake marsh channel cutoffs

Item	1977 prices	1981 prices
First cost	$1,276,900	$1,711,000
Annual cost(1)	93,200	140,500
Annual benefit	53,250	71,400
Benefit-cost ratio	0.57	0.51
Interest rates	6 5/8	7 5/8

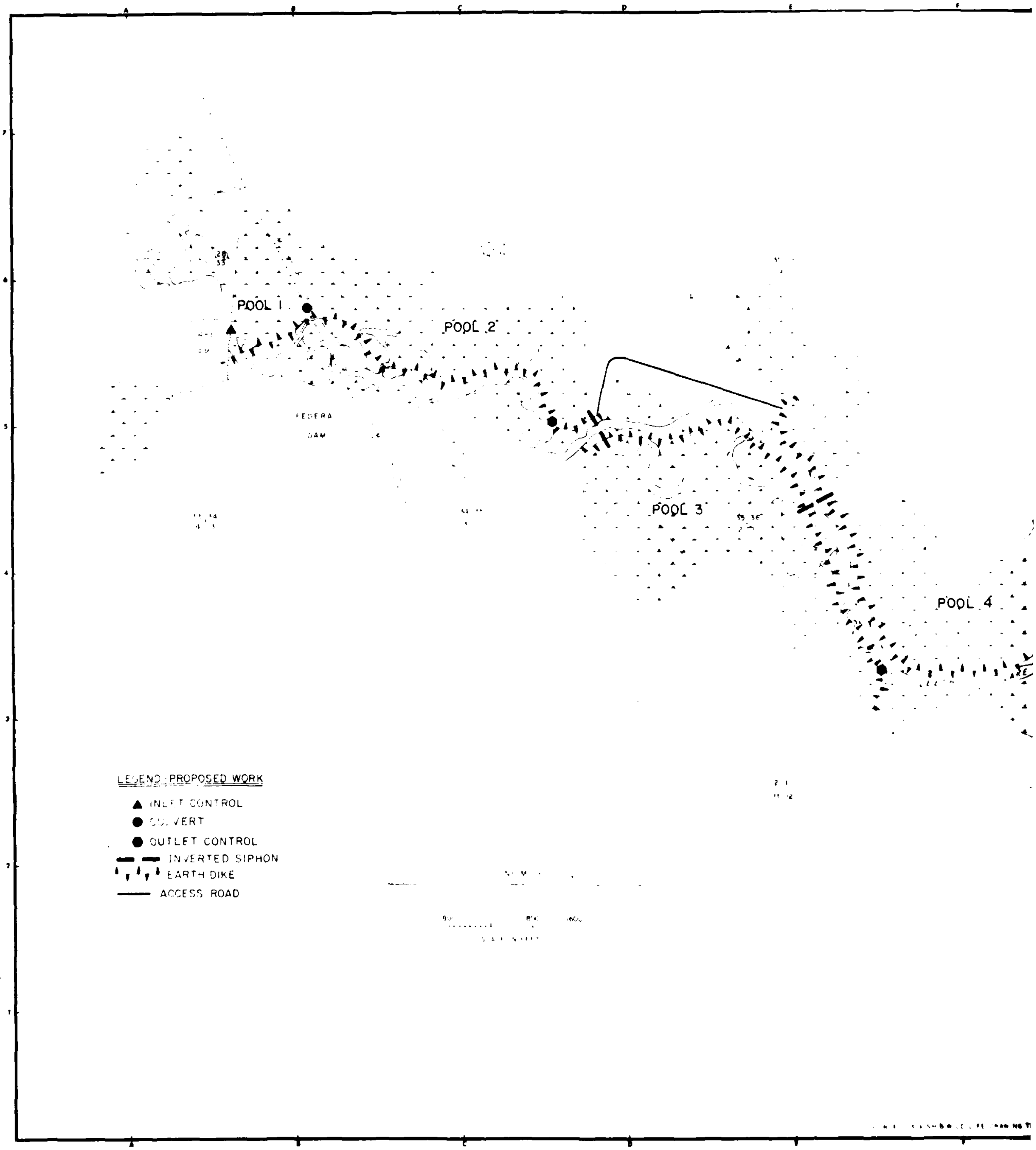
(1) Based on a 50-year project life. Includes operation and maintenance costs.

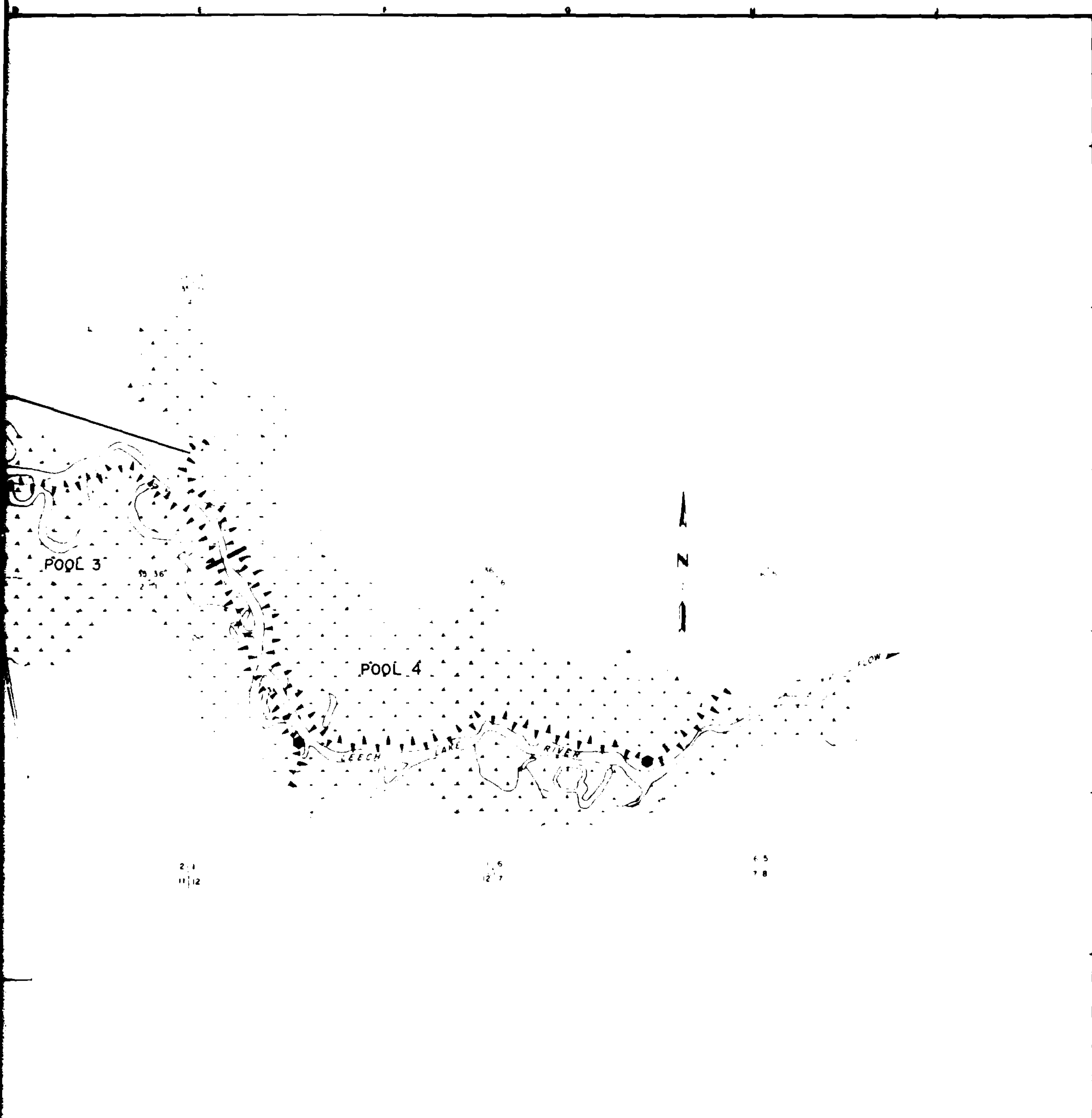
RECOMMENDED ACTION

The development of marsh areas in the 4-mile reach below Leech Lake Dam is not economically feasible. No further action is recommended for this proposed project.

PLATE SUMMARY

Number	Item
A-121	Proposed improvements
A-122	Existing conditions

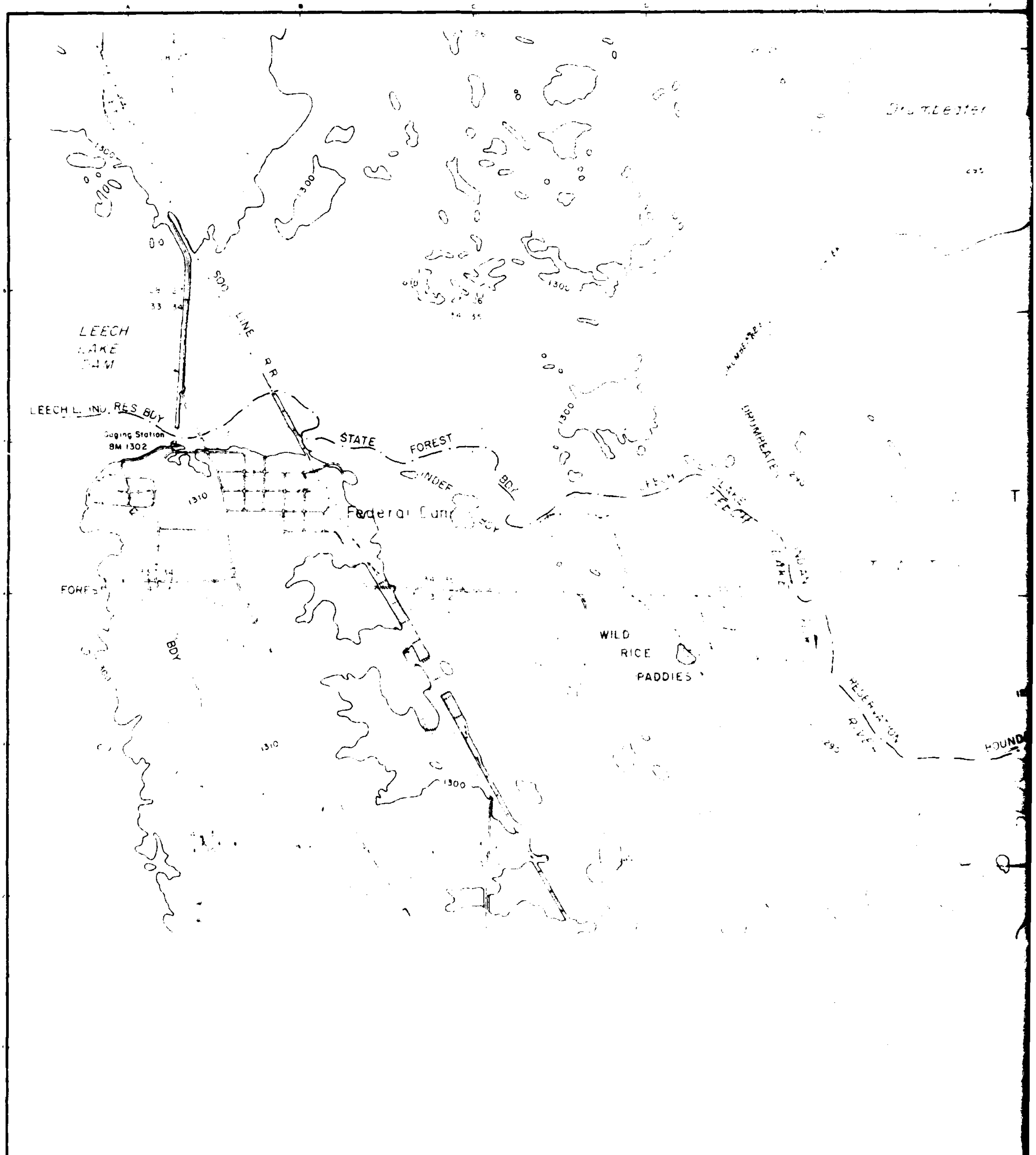

POOL 1
POOL 2
POOL 3
POOL 4
LEGEND: PROPOSED WORK
INLET CONTROL
CULVERT
OUTLET CONTROL
INVERTED SIPHON
EARTH DIKE
ACCESS ROAD



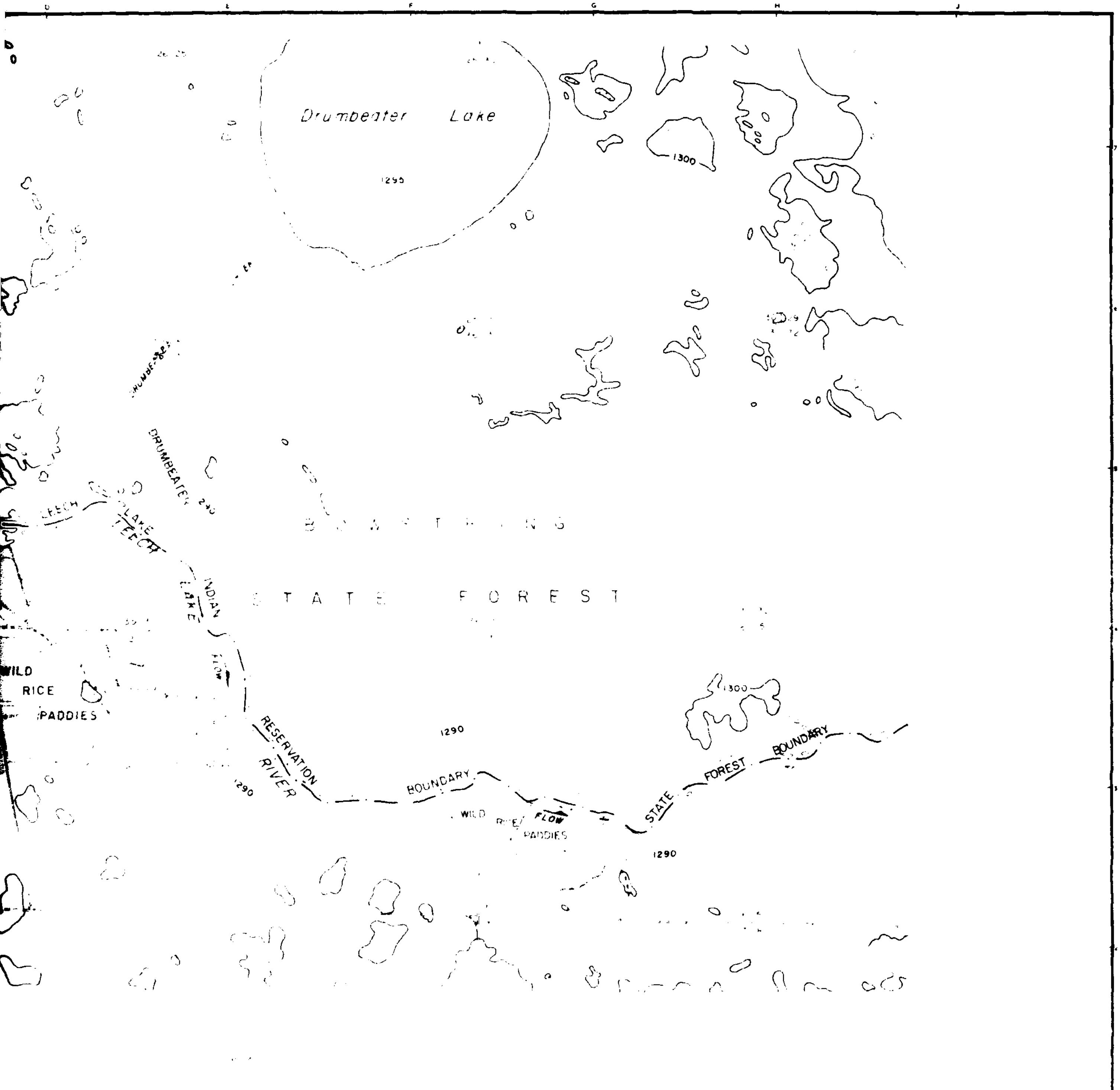
LEECH LAKE RIVER

PROPOSED IMPROVEMENTS

SOURCE: U.S. FISH & WILD LIFE DRAWING TITLED "LEECH LAKE RIVER MARSH RESTURATION DATED 5 FEB 1967



LEECH LAKE DAM
LEECH L. IND. RES BDY
Gaging Station
BM 1302
SOO LINE R R
STATE FOREST BDY
1300
1310
Federal Dam
FOREST BDY
WILD RICE PADDIES
LEECH LAKE INDIAN RESERVATION BOUNDARY
DRUMBEATER



EXISTING CONDITIONS

PROBLEM 9A - LEECH LAKE SUBIMPOUNDMENTS

BACKGROUND

The proposal to construct subdiking on Leech Lake is considered an extension of problem 9, dealing with proposed channel diking downstream of Leech Lake. An alternative to developing the diked-off channel impoundments downstream of Leech Lake Dam would be to develop similar diked impoundments in Leech Lake itself. This alternative was investigated at the request of the Minnesota Department of Natural Resources. The objective of this alternative would be to provide benefits to compensate for fish and wildlife losses that occurred in the area below Winnibigoshish and Leech Lake Dams during the period 1914 to 1926. The potential subimpoundments could provide an alternative to the previously proposed 1,050 acres of diked-off channel impoundments downstream of Leech Lake Dam (problem 9) or to the previously proposed 6,300-acre White Oak Lake development upstream from Pokegama Lake (problem 4).

Four possible subimpoundment locations were first identified on 4 inch = 1 mile recent aerial photographs and on U.S. Geological Survey quadrangle maps of the area. The four areas are shown on plate A-116. The areas were selected to provide somewhat comparable size acreages to the previously proposed downstream Leech Lake River channel impoundments or to the proposed White Oak Lake impoundment. The areas were also selected to provide the least interference with established uses or developments.

A summary of the gross areas identified is shown on plate A-116 and is also listed in the following tabulation:

Site	Bog area	Area (acres)
1	Bowstring	2,300
2	Sugar Point	4,030
3	Boy Lake	1,375
4	Boy Lake	1,050
Total		8,755

Initial evaluation of benefits and costs indicated project feasibility for one of the bog areas (Sugar Point) and near feasibility for another (Bowstring). These initial evaluations assumed development of the entire gross area of each bog for wildlife purposes. However, a closer evaluation using 1976 and 1977 color infrared photography reduced the readily developable acreages at each bog location and resulted in no economically feasible projects. The revised developable acreages are as follows:

Site	Bog area	Area (acres)
1	Bowstring	629
2	Sugar Point	2,800
3	Boy Lake	1,049
4	Boy Lake	574
Total		5,052

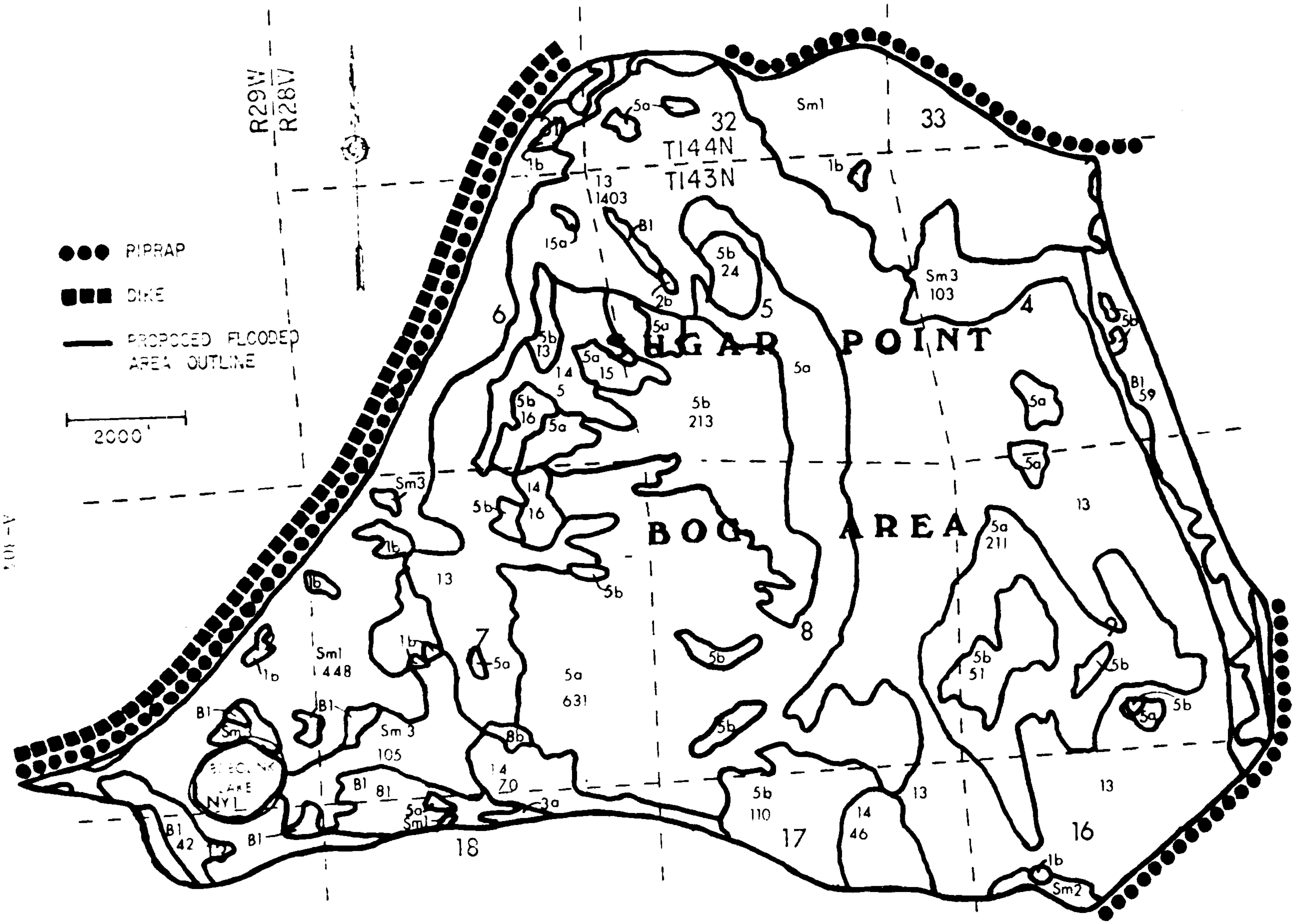
GEOLOGY AND SOILS

No formal program of subsurface investigations was conducted for this area because three of the four Leech Lake subimpoundments did not show economic feasibility in the preliminary analysis. The fourth subimpoundment showed preliminary economic feasibility but was eliminated from further consideration on the basis of subsequent habitat surveys and advice from the U.S. Forest Service and Fish and Wildlife Service.

An extensive wetland habitat survey was conducted of the entire Leech Lake shoreline during 1977 and 1978. The predominant cover types in the four bog areas were found to be sedge meadow bog, floating bog, leather leaf bog, and tamarack. A description of the cover types and their locations in the Sugar Point bog area are shown on the following two figures.

Leech Lake vegetation classification scheme

Category	Symbol	Type Description
1. Aquatic and Marsh	W	Open or apparently non vegetated water.
	10	Submergent plants of medium to heavy density -- some components may occasionally reach the surface. Pondweeds, water marigold, water millfoil and *Chara* sp.
	11	Submergent plants of light or scattered density with the same species mix as Type 10.
	12	Floating pondweed and/or water celery.
	Ny1	Medium to heavy stand of white water lily, usually including a few of the submergent plants found in Types 10 and 11.
	Ny2	Scattered white water lily and occasional submergents.
	Sc	Soft stem bulrush.
	Z	Wild Rice.
	T	Cattail.
	Tm	Cattail marsh -- includes cattail as the dominant and sedges, reed grass, bur reed and willow.
	Pg	Reed grass or flag grass.
	Md	Mud Flat -- mud bottom exposed by lowered water level.
2. Wet-Moist Terrestrial	Sm1	Open, solid bottomed sedge meadow. Sedges are dominant, other plants may include: wetland forbs, alder, bog birch, willow, cattail and reed grass.
	Sm2	Open, floating sedge meadow. Similar to Sm1 in most respects, but the shrub component is more conspicuous.
	Sm3	Brushy, solid sedge meadow. Similar to Sm1 in most respects, but the shrub component is more conspicuous.
	Sm4	Floating brushy sedge meadow.
	13	Open leather leaf bog. Leather leaf is dominant. Also included are: laborador tea, sphagnum moss, cotton grass and sometimes a scattering of tamarack.
	14	Brushy leather leaf bog. Alder and bog birch dominate the overstory. The understory is much like type 13. There may also be as much as 20% crown cover of lowland conifer.
3. Shrubs	B1	Wetland shrub mixture. Willow, alder, dogwood, and bog birch form nearly 100% crown cover -- understory plants are inconspicuous.
	B2	Upland shrub mixture. Thick cover of hazel, alder, round leaf dogwood, and grey stem dogwood.
	B3	Road right of-way mixture of shrubs and grass. Any of the shrub species can be found as well as some small trees and grass.
4. Forest	1a	Aspen birch. Quaking aspen is the dominant species. Others may include paper birch, bigtooth aspen, and balsam poplar. Average stand height is less than 20 feet.
	1b	The same species content as 1a, but average stand height is 20 feet or greater.
	2a	Upland hardwoods -- sugar maple, basswood, white oak, and red oak. Average stand height is less than 20 feet.
	2b	The same species content as 2a, but average stand height is 20 feet or greater.
	4	Beaver killed forest. Present vegetation is lacking or not possible to identify under the dead trees.
	5a	Tamarack -- mostly tamarack, but may include a small amount of other lowland conifers.
	5b	The same species content as 5a, but stand height is 20 feet or greater.
	6a	Mixed lowland conifer. Black spruce, balsam fir, white cedar, and tamarack. The understory plants are similar to those in a leather leaf bog. Average stand height is less than 20 feet.
	6b	The same species content as 6a, but stand height is 20 feet or greater.
	7a	Upland conifer. White pine, red pine, and jack pine. This type can contain a substantial mixture of hardwoods. Stand height is less than 20 feet.
	7b	The same species content as 7a, but stand height is 20 feet or greater.
	8a	Mixture of aspen birch and balsam fir. Stand height is less than 20 feet.
	8b	The same species content as 8a, but stand height is 20 feet or greater.
5. Open Terrestrial	A	Agricultural -- cultivated crops and pasture land (including commercially grown wild rice).
	G	Grass that is not apparently agricultural.
	S	Sand beach or sand bar.
	15a	Recent clear cut.
	15b	Recent partial cut -- a thin tree overstory remains.
6. Developments	D	Bare mineral soil or pavement -- gravel pits, stone quarries, or large construction sites.
	H	Man made boat harbor.
	RS	Resort or other recreational site.
	R	Residential -- houses, lawns, shrubs, and trees.
7. Physical Features and Boundaries	....	Beaver dam
	xxxx	Man made dam
		Paved highway
	——	Type boundary (3/0 drafting pen)
	▬▬	Project boundary (no. 2 drafting pen)



B1 · Habitat Type

HYDROLOGY AND HYDRAULIC STUDIES

The four existing bog areas were proposed for subdiking to maintain from 18 inches to 2 feet of water depth to facilitate the growth of wild rice. The proposal was to flood the areas with water depths conducive to growing wild rice and to seed the areas from the air. The four bog areas would also be expected to provide increased pike spawning areas and habitat for furbearers and migrating waterfowl.

An inlet-outlet structure in each of the diked areas would allow some gravity inflow during high water periods, but primary water supply would have to be provided by pumping. The pumping station requirements were based on the ability to provide 2 feet of water depth to each of the pool areas in 1 month.

OTHER DESIGN CONSIDERATIONS

Riprapping would be required on the exposed dike and road sections of impounded pool areas. No riprapping was considered necessary on the lake side of the dikes, where natural vegetation would be retained as a buffer to the main Leech Lake body of water. The dikes would all be constructed by dragline and compacted and smoothed by bulldozer.

COST ESTIMATE

The Sugar Point bog area (plate A-117) was initially determined to be an economically feasible project using the entire 4,030 acres of gross surface area as being developable. (The other three impoundments were not economically feasible using gross surface areas.) However, the 1977-1978 habitat survey showed that the Sugar Point bog and other areas actually included a significant amount of terrestrial habitat that presently supported tamarack. These tamarack areas could not reasonably be converted to wild rice growing areas by flooding of from 18 to 24 inches

of depth, and developable acreages were reduced to tamarack areas. The Sugar Point bog area was also found to include three eagle nests which, under the Endangered Species Act, would preclude further disturbance or development of the area. Although development of the Sugar Point bog or other bog areas was not found feasible, the cost estimate and benefit analysis for Sugar Point bog are presented as an example of the typical cost estimate prepared for all four areas.

Preliminary estimate of construction costs (Sugar Point bog area)

Item	Unit	Quantity	Unit cost	Total cost (1977 prices)
Dike fill	CY	133,400	$0.75	$100,000
Dike riprap	CY	11,260	20.00	225,200
Gravel filter	CY	5,630	9.00	50,700
Control structure				
20-10c slide gate	Each	2	4,500.00	9,000
Concrete gate well	CY	8	400.00	3,200
30-inch concrete pipe	Foot	208	30.00	6,250
140-cfs pump station	Each	1	380,000.00	380,000
North Road riprap	CY	2,370	20.00	47,400
North Road gravel filter	CY	1,190	9.00	10,750
East Road riprap	CY	1,800	20.00	36,000
East Road gravel filter	CY	890	9.00	8,000
Three small earth closure dams	CY	6,700	0.75	5,000
Subtotal				881,500
Land	Acre	4,030	50.00	201,500
Subtotal				1,083,000
Contingencies				216,600
Total				1,299,600
Engineering and design				97,500
Supervision and administration				97,500
Total first cost construction and acquisition				1,494,600
Annualized first cost (50-year life and 6 5/8 percent interest) (0.06909 x $1,494,600)				103,300
Annual pumping cost				5,000
Annual operation and maintenance cost				65,000
Total annual cost				173,300
Total annual benefits(1)				156,700
Benefit-cost ratio = $156,700 / $173,300				0.90

(1) Benefits for the proposal were determined as indicated on the following page.

BENEFITS

Benefits were determined on 2,800 acres of potentially developable wetland areas for wild rice out of 4,030 acres required purchase for the Sugar Point bog area. The benefits are shown in the following tabulation.

Benefits from subdiking Sugar Point bog area

Item	Benefit Per acre(1) 1977	1981	For 2,800 acres 1977	1981
Wild rice	$22.33	29.92	$62,500	$83,800
Waterfowl	20.75	27.80	58,000	77,800
Muskrats	3.95	5.29	11,000	14,800
Mink	1.28	1.72	3,600	4,800
Pike spawning	4.89	6.55	13,700	18,300
Area redevelopment	2.80	3.75	7,900	10,500
Total benefits			156,700	210,000

(1) Benefit values for 1977 provided by the Minnesota Department of Natural Resources.

The following table summarizes benefits and costs for this alternative.

Benefit-cost summary - Sugar Point bog area

Item	1977 prices	1981 prices
First cost	$1,494,600	$2,002,800
Operation and maintenance	70,000	90,000
Total annual cost(1)	173,300	246,600
Annual benefits	156,700	210,000
Benefit-cost ratio	0.90	0.85
Interest rate	6 5/8	7 5/8

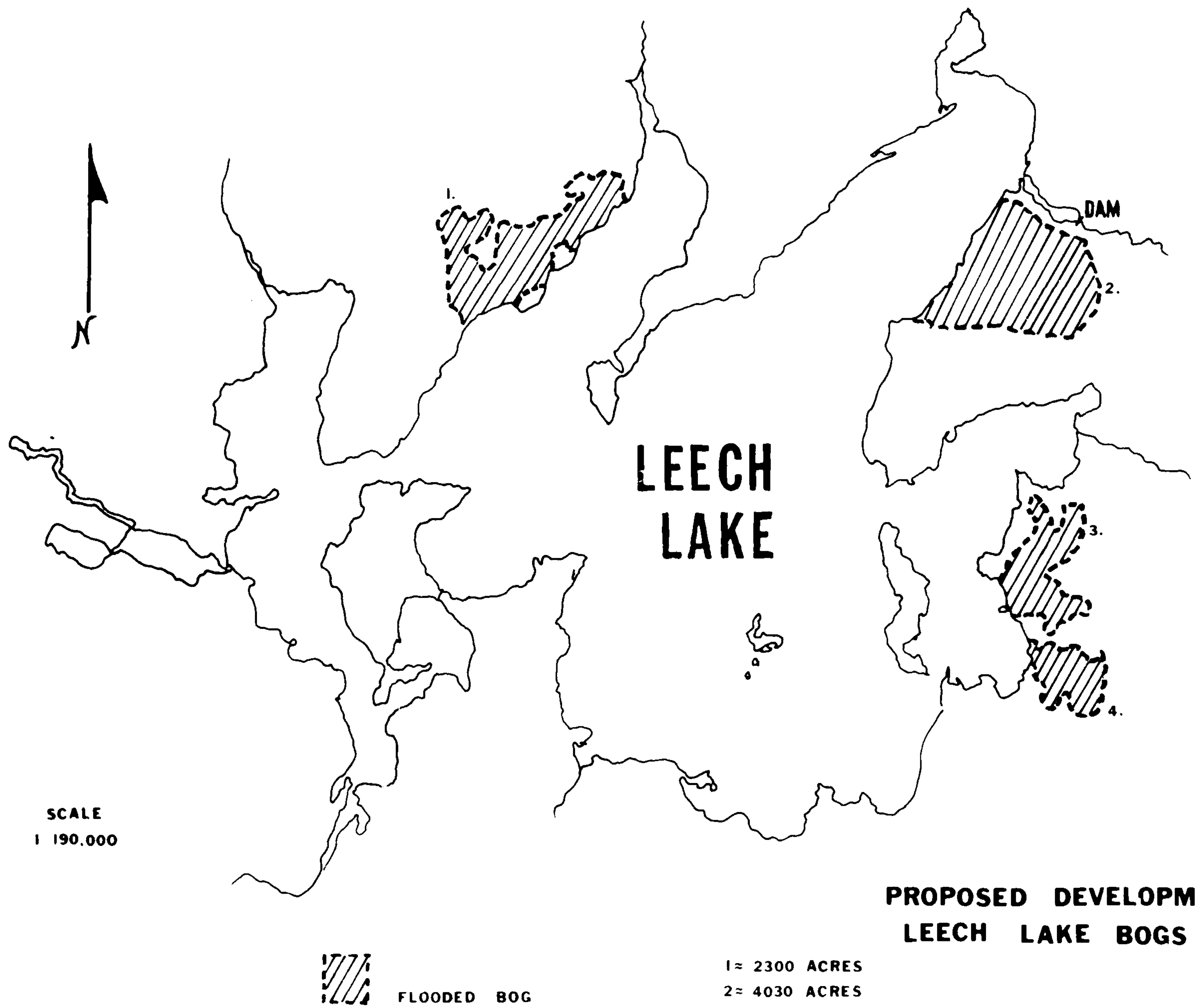
(1) Based on 50-year project life (0.07820 interest and amortization factor).

RECOMMENDED ACTION

The development of subimpoundments to increase wildlife values in the Leech Lake flowage area is not economically feasible. In addition, three eagle nests are located in the Sugar Point bog proposed impoundment area, and any development there would violate the Endangered Species Act. No further action is recommended for the proposed project.

PLATE SUMMARY

Number	Item
A-123	Proposed development - Leech Lake bogs
A-124	Sugar Point bog area



PROPOSED DEVELOPMENT
LEECH LAKE BOGS

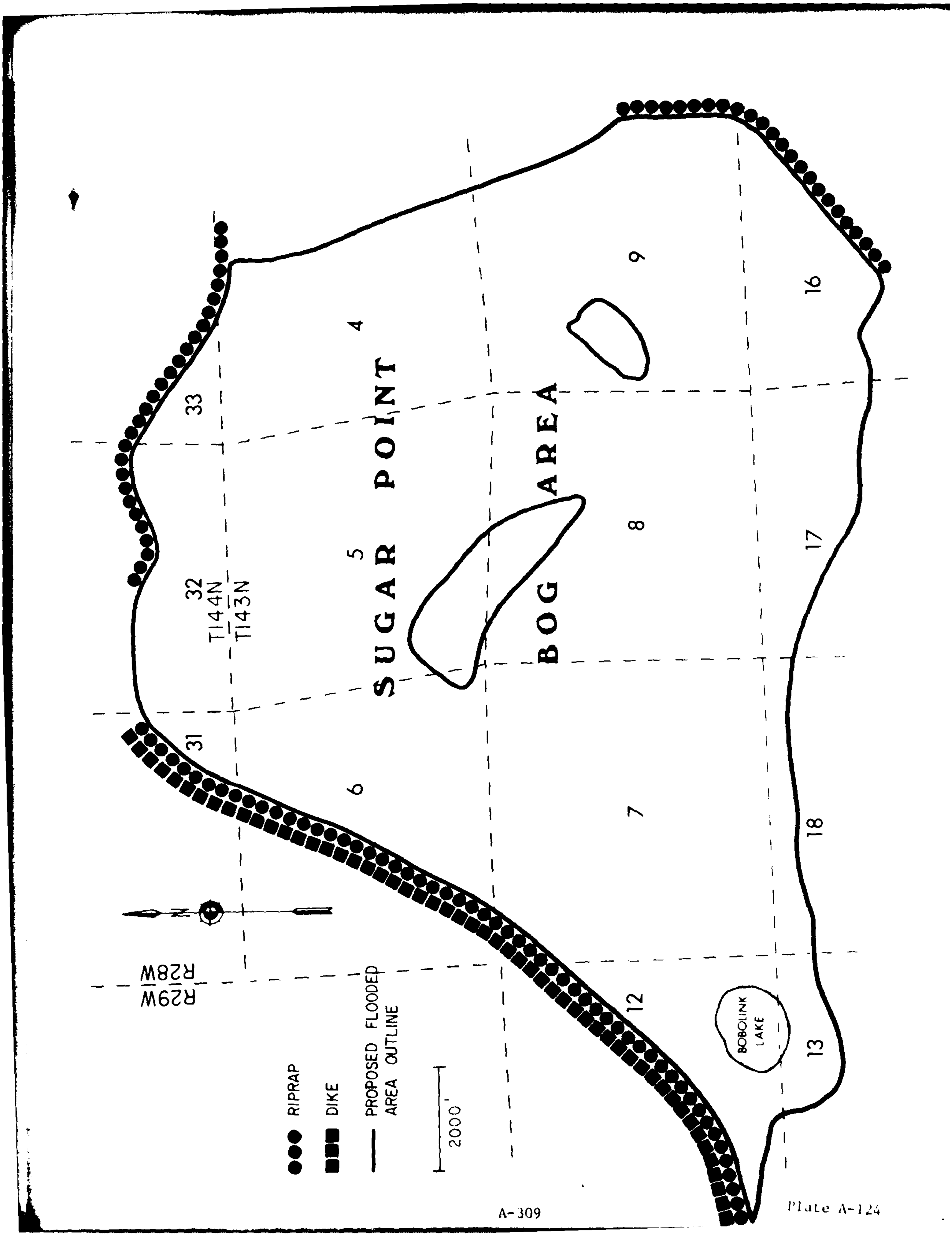

SUGAR POINT
BOG AREA
RIPRAP
DIKE
PROPOSED FLOODED AREA OUTLINE
2000'
R29W
R28W
T144N
T143N
N
31
32
33
6
5
4
7
8
9
12
13
16
17
18
BOBOLINK LAKE

Plate A-124

PROBLEM 10 - AITKIN AREA FLOOD PROBLEM

BACKGROUND

The Aitkin area is a frequently flooded reach of the Mississippi River located approximately between river miles 1040 and 1060, above the mouth of the Ohio River, in Aitkin County, Minnesota. Both agricultural and urban flood damages are common in this river segment. Urban Aitkin had a 1970 population of 1,553 and rural Aitkin consists of about 45 farm units, 35 trailers and other homes, and 16,000 agricultural acres. The 1-percent chance (100-year) flood outline for the Aitkin area is shown on plates A-126 and A-127.

An authorized flood control project was constructed at Aitkin, Minnesota, by the St. Paul District, Corps of Engineers, during 1952-1957. The project consists of approximately 6 miles of diversion channel and related structures just north of Aitkin, and two additional channel cutoffs downstream from that community. The channel is capable of carrying 6,000 cfs, which is about 50 percent of an 8-year frequency flood, with maximum velocity of 2.5 feet per second.

An 8,290-foot emergency levee was constructed at Aitkin by the St. Paul District in 1969 under the Public Law 99 program. This dike protects Aitkin to a 100-year flood with 1 to 2 feet of freeboard but requires emergency dike closures, sandbagging in low areas, and emergency pumping to function properly. The dike system has no interior drainage facilities and was constructed to an average height of 8.5 feet above ground, with a 10-foot top width, and with 1- to 1 1/2-foot side slopes. These levees were constructed under emergency conditions and do not meet acceptable design standards. They could be breached by floods of less than 1 percent (100-year) flood frequency. The existing Aitkin authorized flood control project and emergency dike are shown on plates A-118 and A-119, respectively.

GEOLOGY AND SOILS

General

The Aitkin flooded area is located in the southwestern part of Aitkin County. The Mississippi River flows in a general southwestern direction through the county and crosses the western county line northwest of Aitkin. Sandy Lake is located upstream of Aitkin in the northeastern quarter of Aitkin County. The city of Brainerd is located downstream of Aitkin, in Crow Wing County, about 18 miles west of Aitkin County.

Aitkin County is relatively flat and includes numerous lakes and large areas of poorly drained swamplands. A thick mantle of glacial drift covers the entire surface of Aitkin County and overlies older rock formations. This glacial mantle is 100 to 150 feet thick. This glacial material was deposited from two or three glacial periods. The lowland lying north of Aitkin was the site of glacial Lake Aitkin, which was formed by the partial barrier of glacial material deposited across the Mississippi River channel. Melting water breached the barrier, and allowed the lake to drain, leaving remnants of beach ridges and lacustrine deposits of silt and clay in the old lake area. Extensive peat lands cover approximately 40 percent of the county and average 5 feet in thickness. A large peat or muskeg area extends over 75 to 100 square miles and is located north of Aitkin.

Subsurface Investigation

No formal program of subsurface investigation was conducted for this area as the preliminary analysis of possible solutions to the Aitkin area flood problems did not show economic feasibility. There are extensive borings available, that were taken in the Aitkin area during the early 1950's, in connection with the Aitkin diversion project. Information from these borings indicates that the project area is composed of

lacustrine sand deposited in glacial lake Aitkin, delta sand, and alluvium of tributary streams. The alluvium consists of inorganic silt and some clay. Additional information on subsurface conditions including boring data is included in a February 1952 St. Paul District report entitled "Flood Control Definite Project Report on the Mississippi River Near Aitkin, Minnesota."

HYDROLOGY AND HYDRAULIC STUDIES

General

Hydrology and hydraulic information from several sources was used to evaluate alternative solutions to the Aitkin area flood problem. The sources include a 15 April 1946 survey report for flood control on the Mississippi River near Aitkin, the February 1952 definite project report referred to above, and a June 1975 floodplain information report for the Mississippi River and Ripple River at Aitkin, Minnesota.

Hydrology

The existing Aitkin diversion project, which was built in 1957, bypasses a portion of the Mississippi River to the north of Aitkin and allows the bypassed waters to reenter the Mississippi River at Pine Knoll area (river mile 1040.1). The location of the diversion with respect to Aitkin is shown on plate A-118. The diversion project was designed to handle approximately one-half of a design flow of 12,000 cfs (elevation 1198.2 msl, 1929 adjustment, at the Aitkin USGS gage). The 12,000-cfs flow was assigned a frequency of 17 years (5.9-percent exceedence) for the agricultural season, and a frequency of 12 years (8.3 percent) for annual flooding, when the project was designed in 1952.

The 1952 frequency curve was developed from 49 years of record at the Aitkin, Minnesota, gage. A regional flood frequency for this same flow today (plate A-120) indicates that 12,000 cfs is approximately an 8-year (12.5-percent exceedence) annual flood event. The currently used regional frequency curve was drawn from a correlation of 28 years of record at Aitkin, with 106 years at St. Paul, Minnesota, and with other basin locations and periods of record. Recorded recent flood stage and discharge data for the Mississippi River at Aitkin are shown in the following table. The 100-year (1 percent) and standard project design floods are also shown.

	Estimated peak discharge (cfs)				
Date of crest	Total	Main channel	Diversion	Stage (1)	Elevation (2)
26 March 1945	9,220	9,220	-	17.5	1199.9
27-28 April 1948	12,000	12,000	-	18.8	1201.2
20 May 1950	20,000	20,000	-	22.5	1204.9
15 April 1952	10,000	10,000	-	17.7	1200.1
14 August 1953	10,800	10,800	-	18.2	1200.6
6-7 May 1954	9,480	9,480	-	17.7	1200.1
26 April 1965	13,400	7,500	5,900	17.6	1200.0
23 April 1969	14,400	7,800	6,600	17.3	1199.7
4 May 1975	14,300	7,800	6,500	18.0	1200.4
100-year flood	19,700	10,700	9,000	21.6	1204.0
Standard project flood	34,000	20,000	14,000	25.0	1207.4

DATA SOURCE: June 1975 Floodplain Information Report by U.S. Army Corps of Engineers. The United States Geological Survey and the National Weather Service maintain a water stage recorder on the Mississippi River at mile 1055.9 north of Aitkin near the County Highway 1 bridge. A gaging station at this location has been in operation since 1945.

(1) Overbank flooding begins at a stage of 12 feet (flood stage); damage to structures at about 17 feet. Gage zero is elevation 1182.41. Gage was formerly set with zero at elevation 1185.41 but was set at the present elevation on 30 September 1967.

(2) Feet, mean sea level datum, 1929 adjustment.

Evaluation of the existing project (Aitkin diversion plus main channel flow) indicates that the project is functioning as designed, and is handling the 12,000-cfs flow as planned. Examination of the 1975 flood (14,300 cfs), 1969 flood (14,400 cfs), and 1965 flood (13,400 cfs) shows that at mile 1040.1 (Pine Knoll) and at Aitkin (mile 1055.9) the observed elevations plot very close to the 1952 original project curve elevations. The following table illustrates this close correlation.

		Elevation (1929 adj.)			
		Aitkin gage (Mile 1056.0)		Pine Knoll gage (Mile 1040.1)	
Year	Discharge (cubic feet per second)	Original project curves	Observed	Original project curves	Observed
1965	13,400	1199.0	1200.02	1197.0	1197.87
1969	14,400	1199.8	1199.73	1197.8	1197.48
1975	14,300	1199.8	1200.37	1197.8	1197.78

The following tabulation is included to show the general origin of flood flows experienced at Aitkin and the division of that flow around and through Aitkin.

Mississippi River headwaters area
(maximum flow in cubic feet per second)

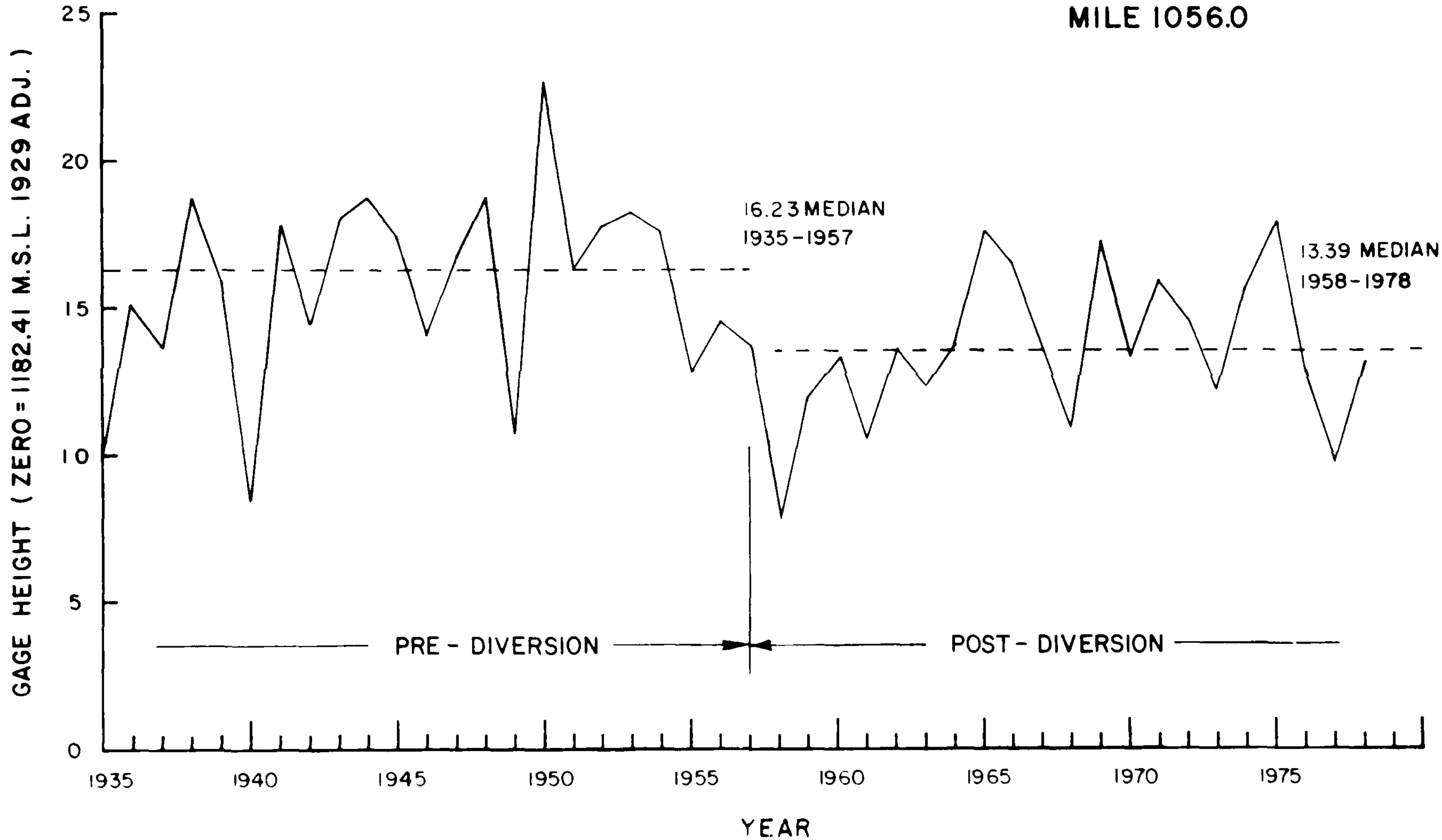
Year	Mississippi River near Grand Rapids (3,370 sq mi)	Prairie River[1] near Taconite (360 sq mi)	Sandy Lake Dam (421 sq mi)	Mississippi River below Sandy River near Libby (5,060 sq mi)	Aitkin[2] total flow (diversion plus river) (6,140 sq mi)	Division of flow[2] Diversion	River
1967	2,950	1,020	1,280	5,680	8,520	3,460	5,230
1968	1,880	836	1,680	4,590	5,850	1,690	4,160
1969	4,610	3,260	1,940	9,080	14,400	6,640	7,740
1970	3,120	1,990	1,460	6,140	9,380	4,020	5,360
1971	3,710	2,570	2,120	8,300	12,200	5,730	6,450
1972	2,800	1,540	1,880	7,010	10,500	4,740	5,830
1973	2,010	500	975	4,050	6,980	2,670	4,540
1974	3,200	1,910	1,590	4,050	11,000	5,060	6,100
1975	3,860	2,460	1,850	8,770	14,500	6,640	7,910

(1) 516 square miles total at mouth of Prairie River, approximately.
(2) The total flow at Aitkin, as shown, may differ slightly from adding the maximums for the "diversion" and "river." This is because the separate flow maximums may occur on different days than the combined flow.

Original project design profiles included in the 1952 Aitkin diversion channel definite project report projected an approximate 3-foot stage reduction for the 12,000-cfs design flow. It is interesting to note that the 3-foot reduction also appears evident in a comparison of observed annual maximum Aitkin gage heights for the period 1935-1978. The median high water stage since completion of the Aitkin diversion project is approximately 3 feet lower than the preproject stages, as shown in the following figure.

AITKIN MINNESOTA
ANNUAL MAXIMUM GAGE HEIGHTS
MILE 1056.0

NOTE: PRE-1968 STAGES ADJUSTED + 3 FEET, TO CURRENT GAGE ZERO
OFFICIAL FLOOD STAGE 15.0' PRIOR TO 11/78
OFFICIAL FLOOD STAGE 12.0' SINCE 11/78



Design Considerations

Evaluation of desired protection for the city of Aitkin and adjoining rural Aitkin was based on protecting the area from a 100-year flood (19,700 cfs). The urban area would be protected from the 100-year flood which is shown on profile plates A-121 and A-122. The 100-year flood elevation is 1204 msl, 1929 adjustment, at the U.S. Geological Survey gage on County Highway 1 in Aitkin (river mile 1055.9). The difference in water elevation between the 100-year flood and the 12,000-cfs Aitkin diversion design flow is only 5.8 feet. The 1952 elevation-discharge rating curve for the Aitkin area is still valid today. A copy of the curve is shown on plate A-123.

ALTERNATIVES

A brief summary of flood reduction alternatives and criteria that were looked at in the Aitkin area are as follows:

Urban Aitkin

Flood insurance. - Flood insurance costs were developed using nationally accepted emergency rates for Aitkin as follows:

Residential structures - $0.25 per $100 market value.
Residential contents - $0.35 per $100 market value.
Commercial structures - $0.40 per $100 market value.
Commercial contents - $0.75 per $100 market value.

The above rates were applied to 200 residential and 44 commercial units which were identified as being flooded in 1950, from the 1975 flood plain information report. The actual computation is included later in this narrative as an example.

Flood warning and forecasting and emergency protection. - This item is adequately described in the main plan formulation report.

Flooded area evacuation. - Permanent evacuation of approximately 200 homes and 44 commercial units from the urban area floodplain is included in this alternative. Permanent evacuation would involve purchase of lands, removal and relocation of improvements, evacuation and resettlement of residents, and permanent conversion of evacuated lands to park or "natural" areas, or to purposes less susceptible to flood damage.

Flood proofing. - This alternative would involve raising approximately 200 homes and 44 businesses and utilities above the 100-year flood elevation 1204. The selected height would be about 1207, although some units possibly could be flood proofed by sealing off building openings and otherwise preventing water from entering window wells and floor drains.

Permanent levee. - A permanent levee would involve construction as shown on plate A-125. The existing emergency levee would be used as a base for the permanent levee after the vegetation and other poor material are first removed. Interior drainage would be collected in a system of inclosed concrete drains and delivered to three pumping stations. The plan would include two road raises, one new bridge and one raised bridge, four elevated road ramps, and two new sewage lift station pumps (one for standby operation). The permanent levee would protect most of Aitkin from the 100-year flood, with 3 feet of freeboard. Highway and railroad access would be maintained through Aitkin during flood periods. A detailed cost estimate is included later in this narrative.

Rural Aitkin

Flood insurance. - Flood insurance costs were developed for rural Aitkin similar to urban Aitkin. The National Flood Insurance Program protects against losses to buildings and contents, but not against agricultural losses. The costs of the program were based on insuring approximately 45 farm residences and 35 other riverside residences downstream from Aitkin. A detailed cost analysis is included later in this narrative.

Flood warning and forecasting services and emergency protection. - (same as for urban Aitkin)

Flooded area evacuation. - Permanent evacuation of approximately 45 farm units and 35 trailers and homes from the area floodplain is included in this alternative. Permanent evacuation would involve purchase of lands, removal and relocation of buildings and improvements, evacuation and resettlement of residents, and permanent conversion of evacuated land to uses less susceptible to flood damage.

Flood proofing. - This alternative would involve ring diking the 45 farm units and 35 riverside residences. Dikes would have a 10-foot top width and 2 on 1 side slopes and would be grass covered. An earth fill exit ramp would be provided for entrance and exit to the diked areas.

Removal of Pine Knoll ledge. - The "Pine Knoll ledge" involves a 10-mile reach of the Mississippi River downstream from Aitkin and from Pine Knoll, between river mile 1030.3 and 1040 approximately. The alternative involves excavating a 150-foot bottom channel with side slopes 1V to 4H, with starting elevation 1175 at mile 1040 and 1171.2 at mile 1030.3. The excavation is primarily waterborne sediment with some gravel or rock bars. Approximately 2,000,000 yards of excavation would lower the Mississippi River approximately 3.2 and 2.8 feet at Pine Knoll (mile 1040) for a 12,000- and 20,000-cfs flow, respectively,

in the Mississippi River channel. This would provide approximately $168,000 reduction in average annual flood damages, assuming that this same reduction would carry upstream past the urban Aitkin area.

The concept of excavating a deeper channel on the Mississippi River downstream of Pine Knoll was evaluated in several previous Corps of Engineers reports. House Document 282 and 599 in 1911 and 1947, respectively, both contain letters from the Chief of Engineers indicating that a proposal of this nature is not economically feasible.

Evacuation of flooded farmsteads. - This alternative would not involve the purchase of agricultural lands from agricultural owners. Only the rural residents, buildings, and improvements would be evacuated from the floodplain. Evacuation would remove 45 farm units and 35 trailers and homes from the floodplain. The agricultural land would be farmed as usual.

Rural river channel diking. - This alternative consists of constructing earth levees along both sides of the natural Mississippi River channel from the inlet to the outlet of the present Aitkin diversion channel (mile 1064 to 1041). The levees would have a top elevation of 1202 and a variable 8- to 10-foot top width, with 1V to 3H and 1V to 5H side slopes. The levee alignment would generally follow the 1,200-foot contour whenever possible along the river and would connect to the existing urban emergency levees. The levees would provide 5 percent or 20-year recurrence interval flood protection with 2 feet of freeboard. The agricultural levees would overtop before the urban emergency levee would be endangered.

There would be approximately 44 miles of low diking with closures on 16 minor drainage courses or tributaries, and would include 12 major pumping stations.

Aitkin and Rural Aitkin

Generally speaking, Aitkin and rural Aitkin alternatives are obtained by adding urban and rural costs and benefits together. Exceptions to this approach are contained in alternatives that aid both areas simultaneously as follows:

Upstream dam above Aitkin. - This alternative consists of constructing a flood control dam on the Mississippi River just downstream of the Rice River. The dam would be designed to store 340,000 acre-feet of floodwater, which is the amount by which the 1950 flood exceeded the present 12,000-cfs Mississippi River and channel diversion capacity, through and around Aitkin.

The terrain is so flat and watersheds interconnected above the damsite that, with a top of dam elevation at 1215 and a maximum flood pool of 1210 to 1212, approximately 80 square miles (51,000 acres) would flood upstream of the dam, in comparison to the protected 25 square miles (16,000 acres) below the dam.

The concept of added flood storage upstream of Aitkin was also evaluated in previous Corps of Engineers reports in 1933 and 1947. Letters from the Chief of Engineers are contained in House Documents 66 and 599, respectively, and confirm that "there are no additional reservoir possibilities so located as to be of significant benefit in the control of floods at Aitkin. . . ."

Diversion (Cedar Brook to Towhead Rapids). - This alternative consists of a 37,000-foot long channel that would divert Mississippi River flows at Cedar Brook (mile 1045) to Towhead Rapids (mile 1030.3). The diversion channel would carry half the 100-year design flow of 19,700 cfs at Aitkin.

Hydraulic computations show that a channel bottom width of 230 feet would be required, with 3:1 side slopes, starting bottom elevation of 1178.7, and ending bottom elevation of 1177.7. Additional modification of the existing Aitkin diversion channel would also be required to make the Cedar Brook channel diversion channel effective. The Cedar Brook diversion channel would alleviate flooding in urban areas downstream of Aitkin but would only partially alleviate the 100-year flood damages in Aitkin and upstream rural areas.

Enlarge Aitkin diversion and remove Pine Knoll ledge. - This alternative consists of enlarging the existing Aitkin diversion channel to pass 14,700 cfs with the main channel through Aitkin passing the remainder of the flow (5,000 cfs). The Pine Knoll ledge removal would be as previously stated also.

The Aitkin diversion channel with present bottom elevation of 90 feet would have to be enlarged to 560 feet. The combined work would lower the 100-year flood stage at Aitkin by approximately 3 feet.

Towhead Rapids channel cutoff. - This alternative would involve constructing a channel cutoff upstream of Towhead Rapids, at approximately mile 1031.5-1032.5 on the Mississippi River. This cutoff could possibly reduce flood levels in the Pine Knoll (mile 1040.1) and Aitkin (mile 1056.0) areas by one-half foot maximum. The channel cutoff would be similar to the Towhead Rapids cutoff immediately downstream, that was constructed in 1957, at mile 1030.5-1031.5. The cutoff would have a 35-foot bottom at elevation 1172, 1V to 3H side slopes, and 40-foot berms on each side, with spoil material placed to a 20-foot height outside the berm areas. The total width required for construction would be about 700 feet.

Modification of Brainerd Dam. - Hydraulic calculations show that the Brainerd power dam at mile 1003.7 has no effect on the Pine Knoll area. The dam is about 36 miles downstream of Pine Knoll and the backwater effects of the dam extend only about 23 miles upstream of the dam.

Evaluation

The following table summarizes the cost-benefit analysis for Aitkin area alternatives. Later paragraphs address in more detail the specific cost estimates and benefits that were originally prepared at 1977 price levels and which have now been updated to 1981 price levels.

Summary of Aitkin, Minnesota, flood control alternatives

Alternative	First cost	Annual cost (1)	Maximum annual benefit	Benefit-cost ratio
Urban Aitkin				
1. Flood insurance	-	$282,000	$282,000 (3)	1.0
2. Flood forecasting and warning (5)	-	-	-	-
3. Evacuation	$22,898,000	1,747,000	45,600	0.03
4. Flood proofing	1,956,000	149,300	32,100 (2)	0.21
5. Permanent dike	5,242,000	446,600	45,600	0.10
Rural Aitkin				
1. Flood insurance	-	57,400	57,400 (3)	1.0
2. Flood forecasting and warning (5)	-	-	-	-
3. Evacuation	[illegible]2,696,000	2,495,000	225,000	0.09
4. Flood proofing	1,490,000	188,700	46,500	0.25
5. Removal of Pine Knoll ledge	6,901,000	548,300 (6)	225,000	0.41
6. Evacuation with no land purchase	5,302,000	404,500	46,500	0.11
7. Rural river channel diking	17,688,000	1,403,600	Less than 225,000	0.16
Aitkin and rural Aitkin (4)				
1. Flood insurance	- -	339,300	339,300 (3)	1.0
2. Flood forecasting and warning (5)				
3. Evacuation	55,594,000	4,242,000	270,800	0.06
4. Flood proofing	3,446,000	337,600	78,700	0.23
5. Upstream dam above Aitkin	36,180,000	2,796,000	270,800	0.10
6. Diversion (Cedar Brook to Towhead Rapids)	46,955,000	3,707,000 (6)	270,800	0.07
7. Enlarge Aitkin diversion and Pine Knoll excavation	87,187,000	6,958,999	270,800	0.04
8. Towhead Rapids channel cutoff	1,828,000	145,500 (6)	47,800	0.32
9. Modify Brainerd Dam	(Would not be effective - no cost estimate determined)			

(1) Includes operation and maintenance costs; 7 5/8 percent interest and 100-year project life, except where indicated.

(2) 100-percent flood proofing in Aitkin is not possible because of permeable soils - use 70 percent x $45,700 = $32,100 annual benefits.

(3) Flood insurance benefits assumed equal to flood insurance costs.

(4) Benefits and costs for rural and urban Aitkin are the sum of individual costs and benefits.

(5) Costs and benefits for emergency evacuation or protection measures would vary, depending on magnitude of flood predicted.

(6) 7 5/8-percent interest - 50-year project life.

The previous table shows that there are no economically feasible structural alternatives for alleviating flood problems in the Aitkin area. The Federal flood insurance alternative is purposely assigned a benefit-cost ratio of 1.0, as benefits from the program should equal costs. However, the federally subsidized flood insurance program compensates for losses to structures but does not compensate for livestock or crop losses.

COST ESTIMATES

A detailed flood insurance cost estimate for both urban and rural Aitkin follows. A summarized cost estimate for a permanent levee to protect urban Aitkin and a summarized cost estimate for removal of the Pine Knoll ledge are included for comparison purposes although they lack economic feasibility. A brief discussion of the benefit analysis follows these cost estimates. Costs originally estimated at 1977 prices were subsequently indexed to 1981 prices for this report.

Urban area - flood insurance costs for 100-year floodplain (emergency rates)

Subsidized insurance rates (non-Federal insurance costs)[1]

Residential structures - $0.25(a) per $100 estimated market value.
Residential contents - $0.35(b) per $100 estimated value.

Commercial structures - $0.40(c) per $100 estimated market value.
Commercial contents - $0.75(d) per $100 estimated value.

(1) These rates represent the non-Federal insurance costs (approximately 25 percent of total insurance costs).

Description		Cost (1977 prices)
Residential insurance costs		
Structures: Number of living units x average value = value.		
200 x $20,000 = $4,000,000		
Total estimated market value	$4,000,000 (e)	
Structure insurance costs (a)x(e)		$10,000
Contents: Total estimated value (50 percent of (e))	2,000,000 (f)	
Contents insurance costs (b) x (f)		7,000
Commercial insurance costs		
Structures: Number of structures x average value = value.		
44 x $100,000 $4,400,000		
Total estimated market value	$4,400,000 (g)	

Structure insurance costs (c) x (g) $17,600

Contents: Total estimated value
(50 percent of (g))(2) $2,200,000(h)

(2) Assume 50 percent in lieu of detailed survey.

Contents insurance costs (d) x (h) 16,500

Total insurance costs:	Non-Federal		Federal(3)	
Residential structure	$10,000	x 3	$30,000	
Residential contents	7,000	x 3	21,000	
Commercial structure	17,600	x 3	52,800	
Commercial contents	16,500	x 3	49,500	
Subtotal	51,100	+	153,300	204,400
Insurance administration (non-Federal) - 6 man-months at $1,000				6,000
Total insurance costs				210,400

Note: Total insurance costs are annual costs.

Division of responsibilities:	(1977 prices)	(1981 prices)
Total non-Federal	$51,100	
Costs	6,000	
Total	57,100	
Total Federal costs	153,300	
Total annual costs	210,400	$282,000

Assume average annual benefits equal costs.

(3) Non-Federal costs are 25 percent of total costs (multiply non-Federal cost x 3 to get Federal costs).

Agriculture area - flood insurance costs for 100-year floodplain
(emergency rates)

Subsidized insurance rates (non-Federal insurance costs)(1)

Residential structures - $0.25(a) per $100 estimated market value.
Residential contents - $0.35(b) per $100 estimated value.

Commercial structures - $0.40(c) per $100 estimated market value.
Commercial contents - $0.75(d) per $100 estimated value.

(1) These rates represent the non-Federal insurance costs (approximately 25 percent of total insurance costs).

Description				Cost
Residential insurance costs				
Structures: Number of living units x average value =			Total value	
Farm residences	45± x	$15,000	$675,000	
Riverside units	35± x	8,000	280,000	
Total estimated market value			955,000(e)	
Structure insurance costs (a) x (e)				$2,400
Contents: Total estimated value (50 percent of e)			475,000(f)	
Contents insurance costs (b) x (f)				1,600
Commercial insurance costs:				
Structures: Number of structures x average value = value				
Farm buildings (Approximately 135)	x	$5,000	= $675,000	
Total estimated market value			675,000(g)	
Structure insurance costs (c) x (g)				2,700
Contents: Total estimated value (50 percent of (g))(2)		$337,000(h)		

(2) Assume 50 percent in lieu of detailed survey.

Contents insurance costs (d) x (h)				2,500
Total insurance costs:	Non-Federal		Federal(3)	
Residential structure	$2,400	x 3	$7,200	
Residential contents	1,600	x 3	4,800	
Commercial structure	2,700	x 3	8,100	
Commercial contents	2,500	x 3	7,500	
Subtotal	9,200	+	27,600	36,800
Insurance administration (non-Federal) 6 man-months at $1,000				6,000
Total insurance costs				42,800

Note: Total insurance costs are annual costs.

(3) Non-Federal costs are 25 percent of total costs(multiply non-Federal costs x 3 to get Federal costs).

Division of responsibilities

Total non-Federal cost	$9,200
Costs	6,000
Total	15,200
Total Federal costs	27,600
Total annual costs	42,800

Annual benefits are assumed to equal annual costs for a benefit-cost ratio of 1.0

Cost estimate for Aitkin area urban diking

Item	Unit	Quantity	Unit cost	Total cost	
Federal costs				**1977 prices**	1981 prices
Levee	Lump sum	-		$178,800	
Sanitary pumping stations	Lump sum	2	$108,000	216,000	
Levee pumping stations					
45,000 gpm	Lump sum	1	410,000	410,000	
31,000 gpm	Lump sum	1	340,000	340,000	
36,000 gpm	Lump sum	1	360,000	360,000	
Gravity drainage structures (with gate well)	Lump sum	3	22,200	66,000	
36-inch concrete interior drainage storm sewer collector	Feet	7,500	120	900,000	
Concrete manholes with catch basins	Lump sum	25	1,000	25,000	
Subtotal				2,495,800	
Contingencies				499,000	
Engineering and design				224,600	
Supervision and administration				224,600	
Total Federal first cost				3,444,000	$4,615,000
Non-Federal costs					
Lands	Acre	14.5	2,000	29,000	
County 54 bridge replacement	Lump sum	1	205,800	205,800	
Highway 210 and highway 169 bridge raise	Lump sum	1	99,300	99,300	
36-inch paved CMP road crossing	Job	2	4,000	8,000	
Subtotal				342,100	
Contingencies				68,400	
Engineering and design				28,600	
Supervision and administration				28,600	
Total non-Federal first cost				467,700	627,000
Total first cost				3,911,700	[illegible],242,000
Annualized first cost at 6 5/8- and 7 5/8-percent interest and 100-year life				259,600	399,600
Annual operation and maintenance				35,000	47,000
Total annual cost				294,600	446,600
Total annual benefits				34,100	45,600
Benefit-cost ratio				0.12	0.10

Cost estimate for removal of Pine Knoll ledge for rural Aitkin

Item	Unit	Quantity	Unit cost	Total cost (1977)	Total cost (1981)
Alluvial excavation	CY	2,000,000	$2.20	$4,400,000	$5,896,000
Contingencies (10 percent)				440,000	589,600
Engineering and design				155,000	207,700
Supervision and administration				155,000	207,700
Total first cost				5,150,000	6,901,000
Annualized first cost at 50-year life				355,600	539,700
Annual operation and maintenance				6,400	8,600
Total annual cost				362,000	548,300
Total annual benefit				168,000	225,100
Benefit-cost ratio				0.46	0.41
Interest rate (50-year life)				6 5/8	7 5/8

NOTE: Disposal costs are not included.

BENEFITS

Information on Aitkin area benefits used in the previous cost-benefit analysis and their derivation are included under problem 1, "Headwaters Lake Operating Plans." The benefits derived in that section of the report are used in this analysis also. Basically, 100 percent of urban and rural flood damages were used as project benefits for all the Aitkin alternative proposals. Residual flood damages and more detailed hydraulic analysis would have been necessary if any of the alternatives had shown economic feasibility.

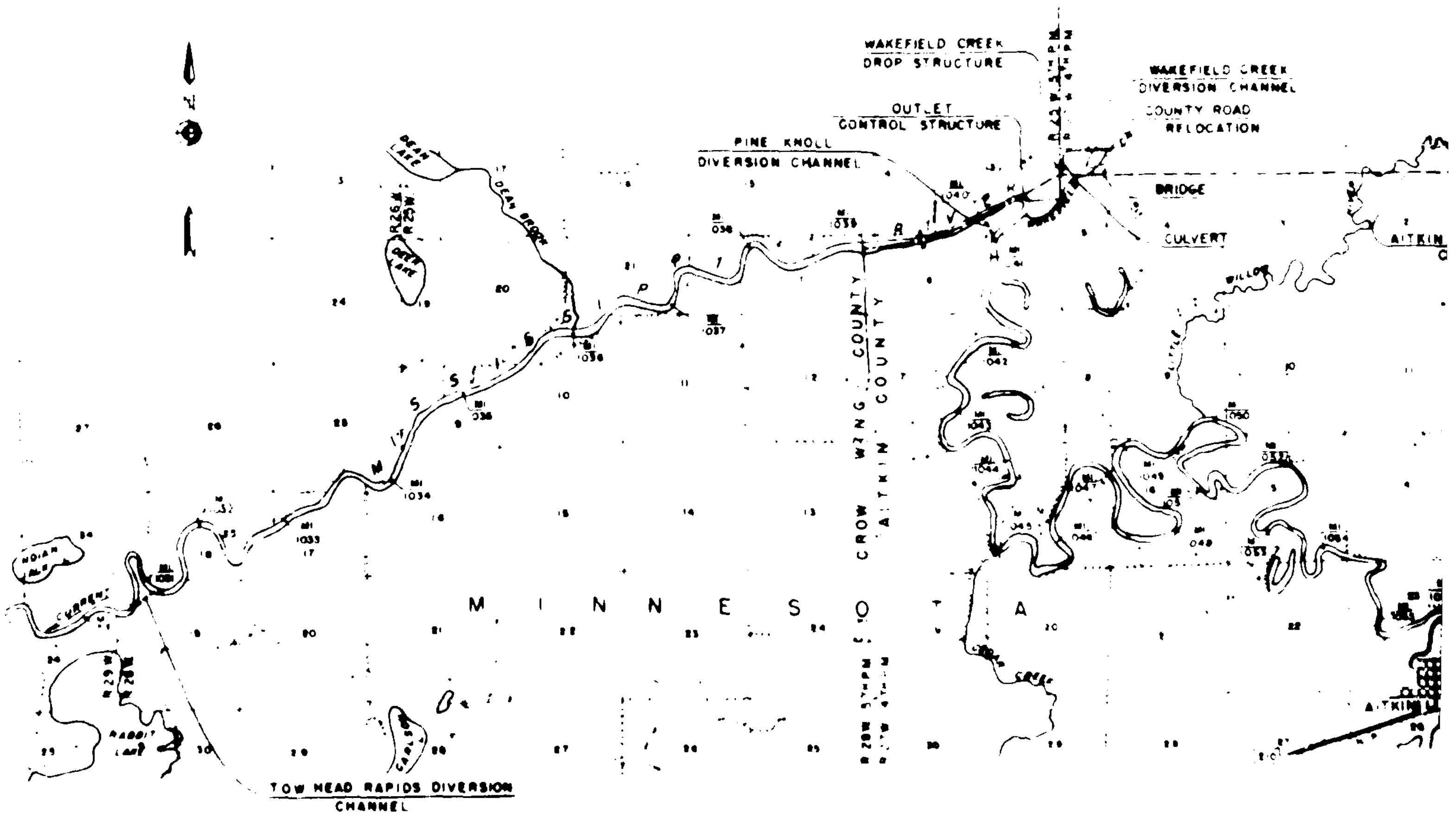
RECOMMENDED ACTION

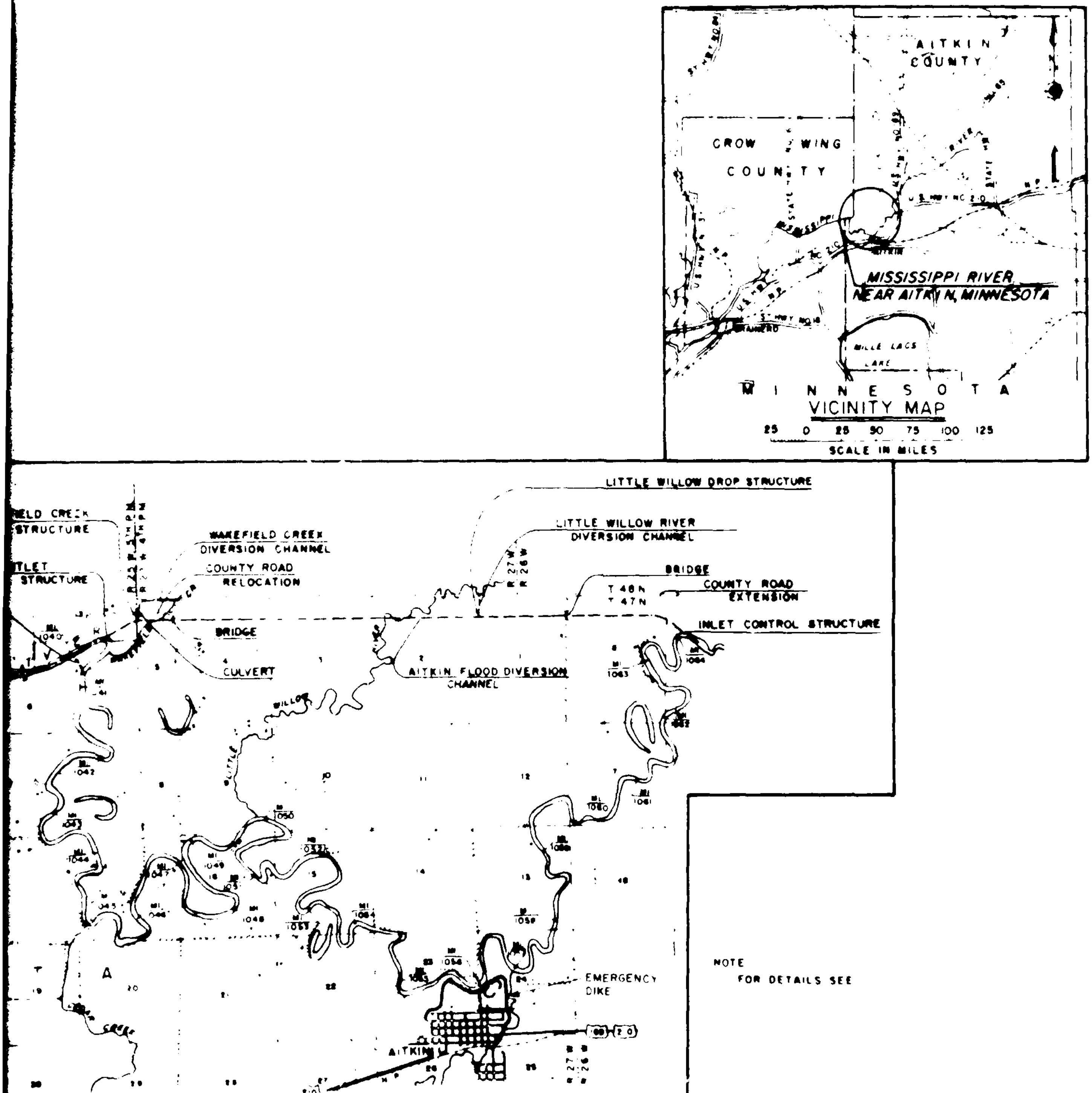
No economically feasible project was developed for the Aitkin project. The recommendation for Aitkin area residents is to purchase flood insurance under the National Flood Insurance program, adopt floodplain zoning regulations to control future development, and use the existing Aitkin diversion channel and emergency dike and flood forecasting and warning services of the National Weather Service. All of these features will provide some protection and economic compensation for the area.

The annual cost for federally subsidized flood insurance is estimated at $51,400 for rural Aitkin and $282,000 for urban Aitkin. This is the estimated cost of insuring approximately 200 homes and 44 businesses in urban Aitkin and 45 farmstead area buildings and 35 trailer units in the adjoining rural community.

PLATE SUMMARY

Number	Item
A-125	Project Map - Flood Control Project near Aitkin.
A-126	Emergency Levee Location.
A-127	Discharge-Frequency at Aitkin.
A-128	High Water Profile.
A-129	High Water Profile.
A-130	Rating Curves.
A-131	Aitkin Alternatives.
A-132	Proposed Levee - Plan and Profiles.
A-133	100-Year Flood Outline (sheet 1)
A-134	100-Year Flood Outline (sheet 2)


WAKEFIELD CREEK
DROP STRUCTURE
WAKEFIELD CREEK
DIVERSION CHANNEL
OUTLET
CONTROL STRUCTURE
COUNTY ROAD
RELOCATION
PINE KNOLL
DIVERSION CHANNEL
BRIDGE
CULVERT
AITKIN
DEAN LAKE
DEAN BROOK
R26W
R25W
CROW WING COUNTY
AITKIN COUNTY
M I N N E S O T A
INDIAN LAKE
RABBIT LAKE
R29W
TOW HEAD RAPIDS DIVERSION
CHANNEL
AITKIN



NOTE
FOR DETAILS SEE

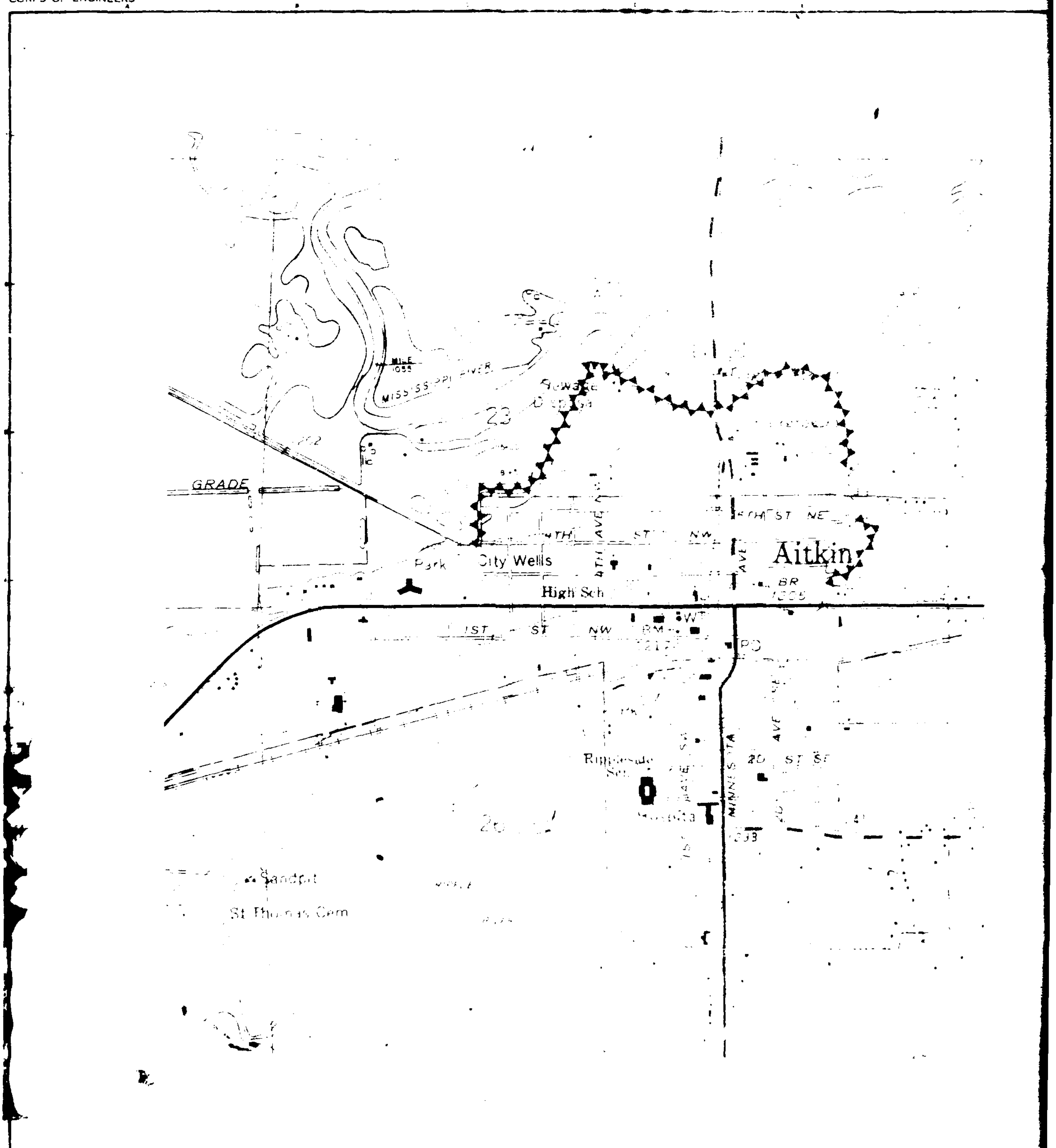
PROJECT MAP
FLOOD CONTROL PROJECT
NEAR AITKIN

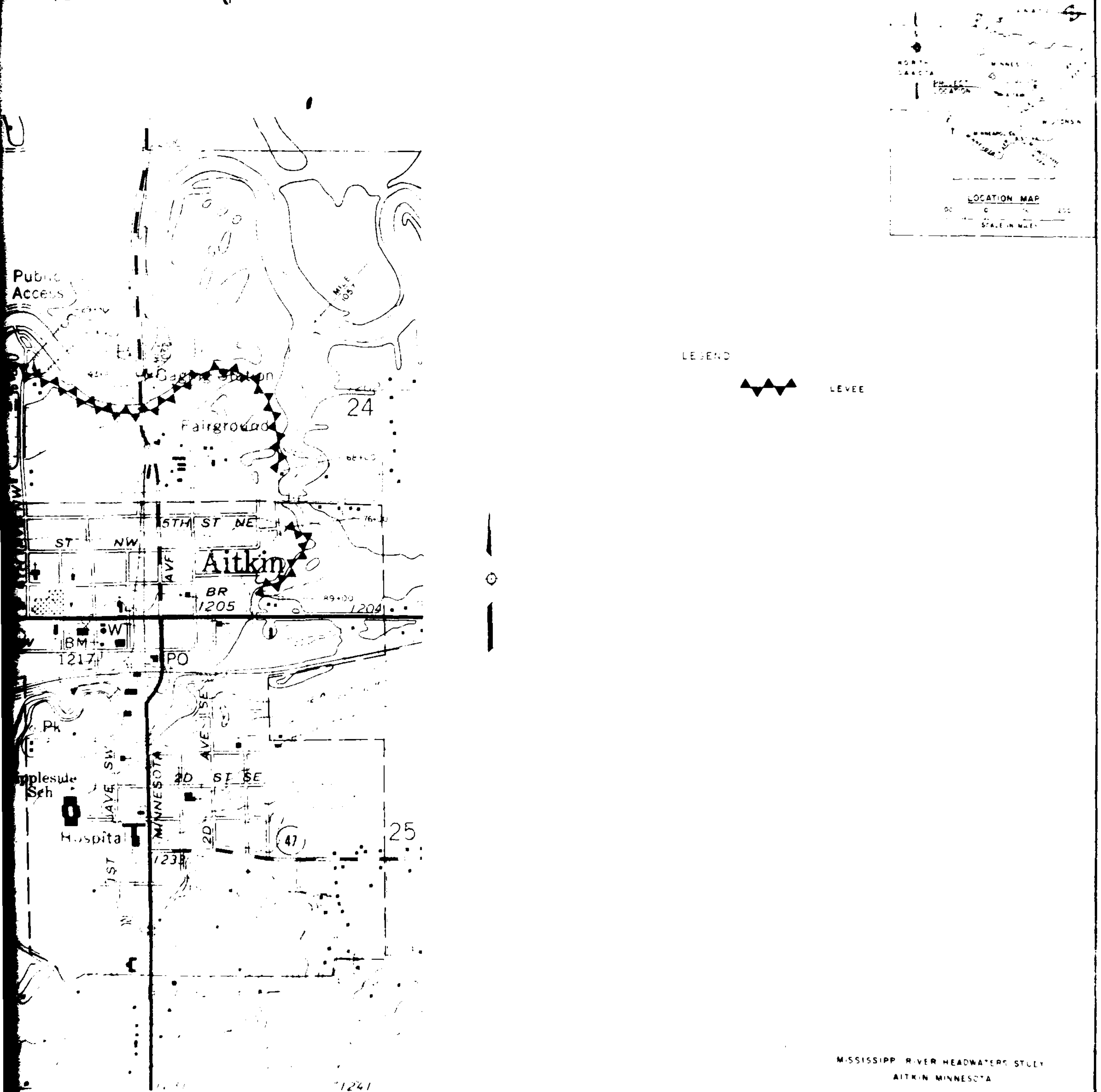
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST PAUL DISTRICT ST PAUL, MINNESOTA

U.S. GPO 1975 665 155/58.6

PLATE A-125

CORPS OF ENGINEERS





MISSISSIPPI RIVER HEADWATERS STUDY
AITKIN MINNESOTA

EMERGENCY LEVEE LOCATION

ST PAUL DISTRICT CORPS OF ENGINEERS

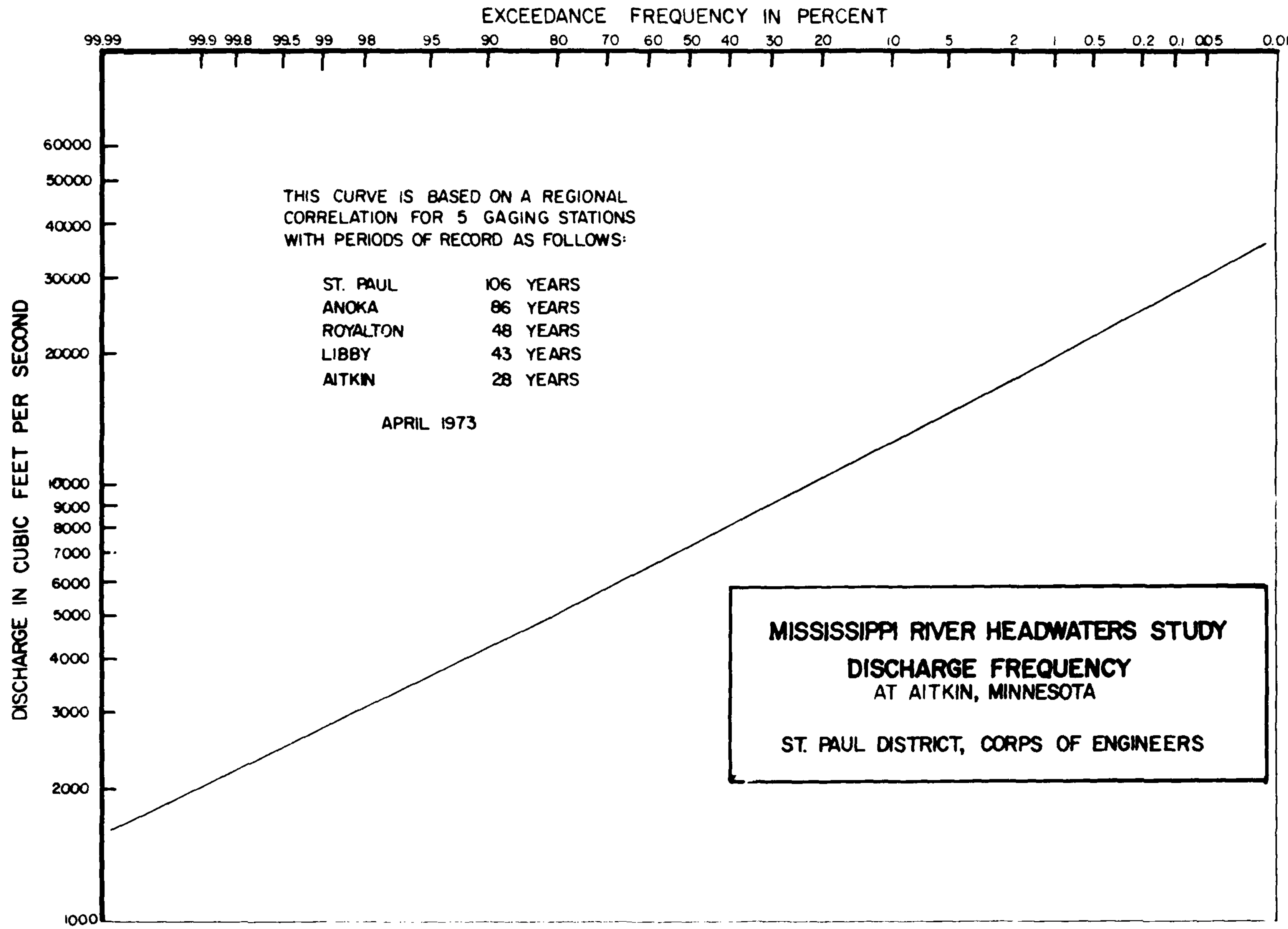
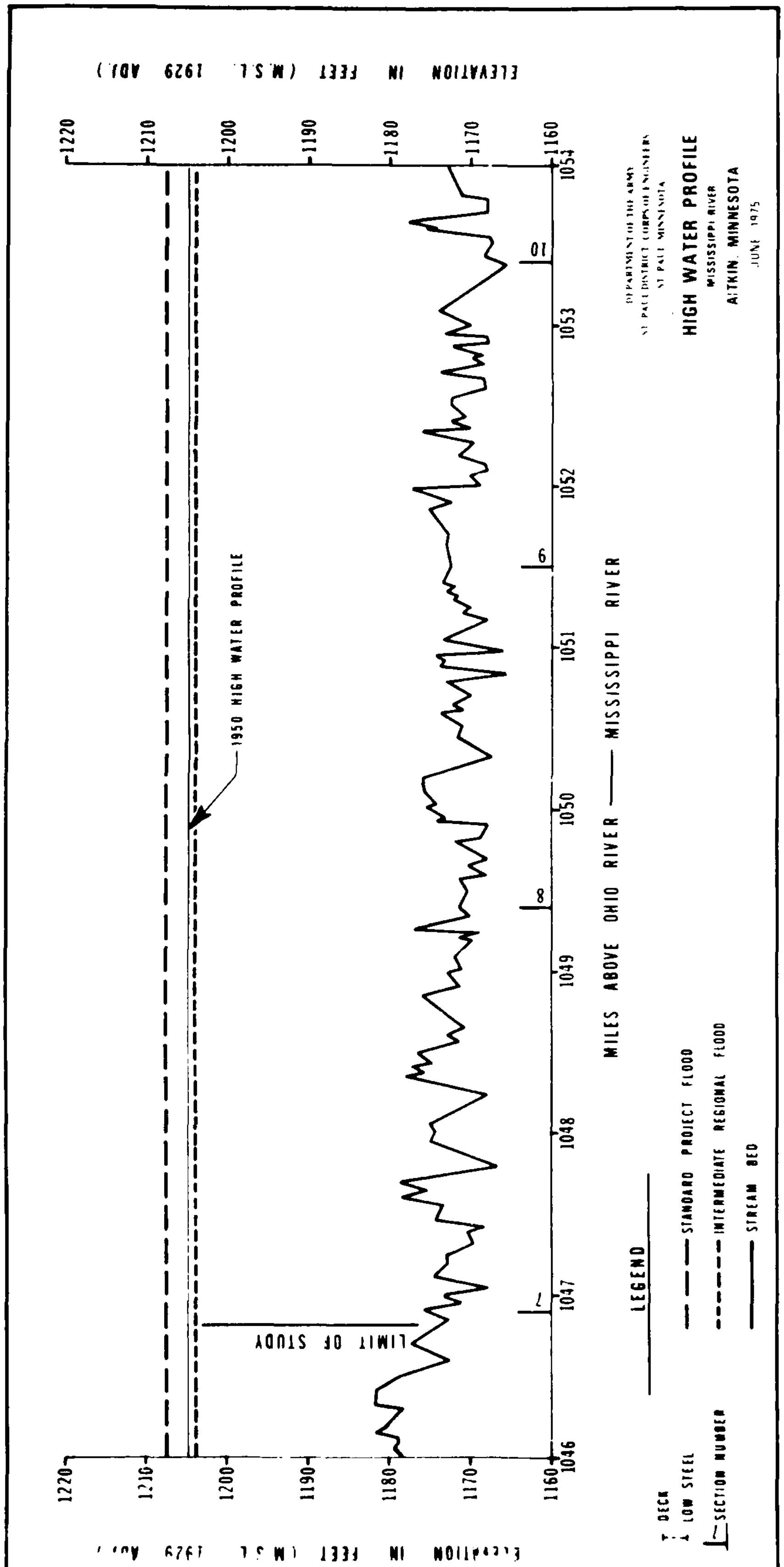
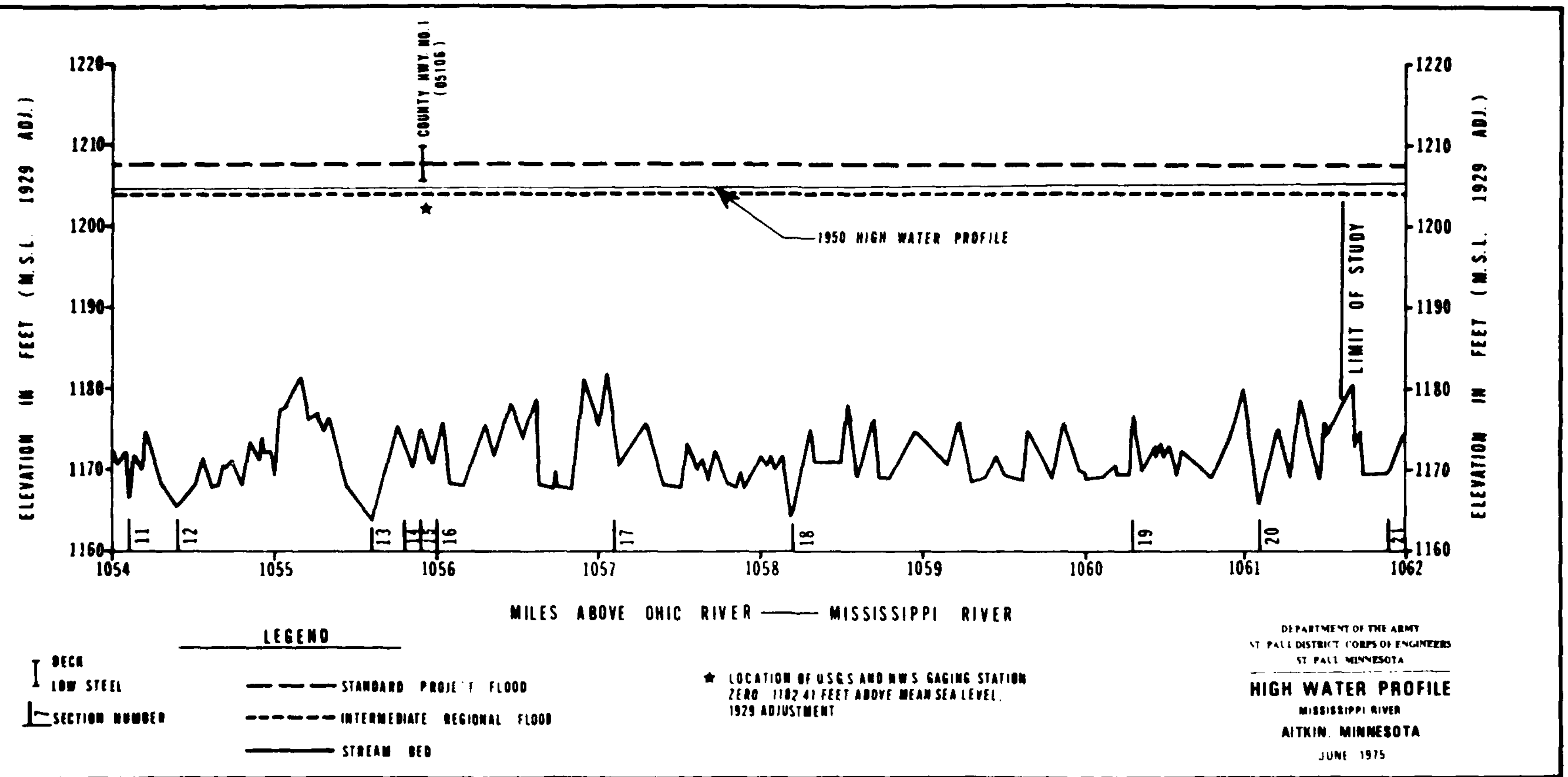

EXCEEDANCE FREQUENCY IN PERCENT
99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
DISCHARGE IN CUBIC FEET PER SECOND
60000 50000 40000 30000 20000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000
THIS CURVE IS BASED ON A REGIONAL CORRELATION FOR 5 GAGING STATIONS WITH PERIODS OF RECORD AS FOLLOWS:
ST. PAUL 106 YEARS
ANOKA 86 YEARS
ROYALTON 48 YEARS
LIBBY 43 YEARS
AITKIN 28 YEARS
APRIL 1973
MISSISSIPPI RIVER HEADWATERS STUDY
DISCHARGE FREQUENCY
AT AITKIN, MINNESOTA
ST. PAUL DISTRICT, CORPS OF ENGINEERS

PLATE A-127


DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL MINNESOTA
HIGH WATER PROFILE
MISSISSIPPI RIVER
AITKIN, MINNESOTA
JUNE 1975
ELEVATION IN FEET (M.S.L. 1929 ADJ.)
1220
1210
1200
1190
1180
1170
1160
1046
1047
1048
1049
1050
1051
1052
1053
1054
7
8
9
10
1950 HIGH WATER PROFILE
LIMIT OF STUDY
MILES ABOVE OHIO RIVER —— MISSISSIPPI RIVER
LEGEND
STANDARD PROJECT FLOOD
INTERMEDIATE REGIONAL FLOOD
STREAM BED
DECK
LOW STEEL
SECTION NUMBER



ELEVATION IN FEET (M.S.L. 1929 ADJ.)
1220
1210
1200
1190
1180
1170
1160
COUNTY HWY. NO. 1 (05106)
1950 HIGH WATER PROFILE
LIMIT OF STUDY
11
12
13
16
17
18
19
20
21
1054
1055
1056
1057
1058
1059
1060
1061
1062
MILES ABOVE OHIC RIVER —— MISSISSIPPI RIVER
LEGEND
DECK
LOW STEEL
SECTION NUMBER
STANDARD PROJE'T FLOOD
INTERMEDIATE REGIONAL FLOOD
STREAM BED
★ LOCATION OF U.S.G.S AND N.W.S. GAGING STATION
ZERO 1102.41 FEET ABOVE MEAN SEA LEVEL.
1929 ADJUSTMENT
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL MINNESOTA
HIGH WATER PROFILE
MISSISSIPPI RIVER
AITKIN, MINNESOTA
JUNE 1975

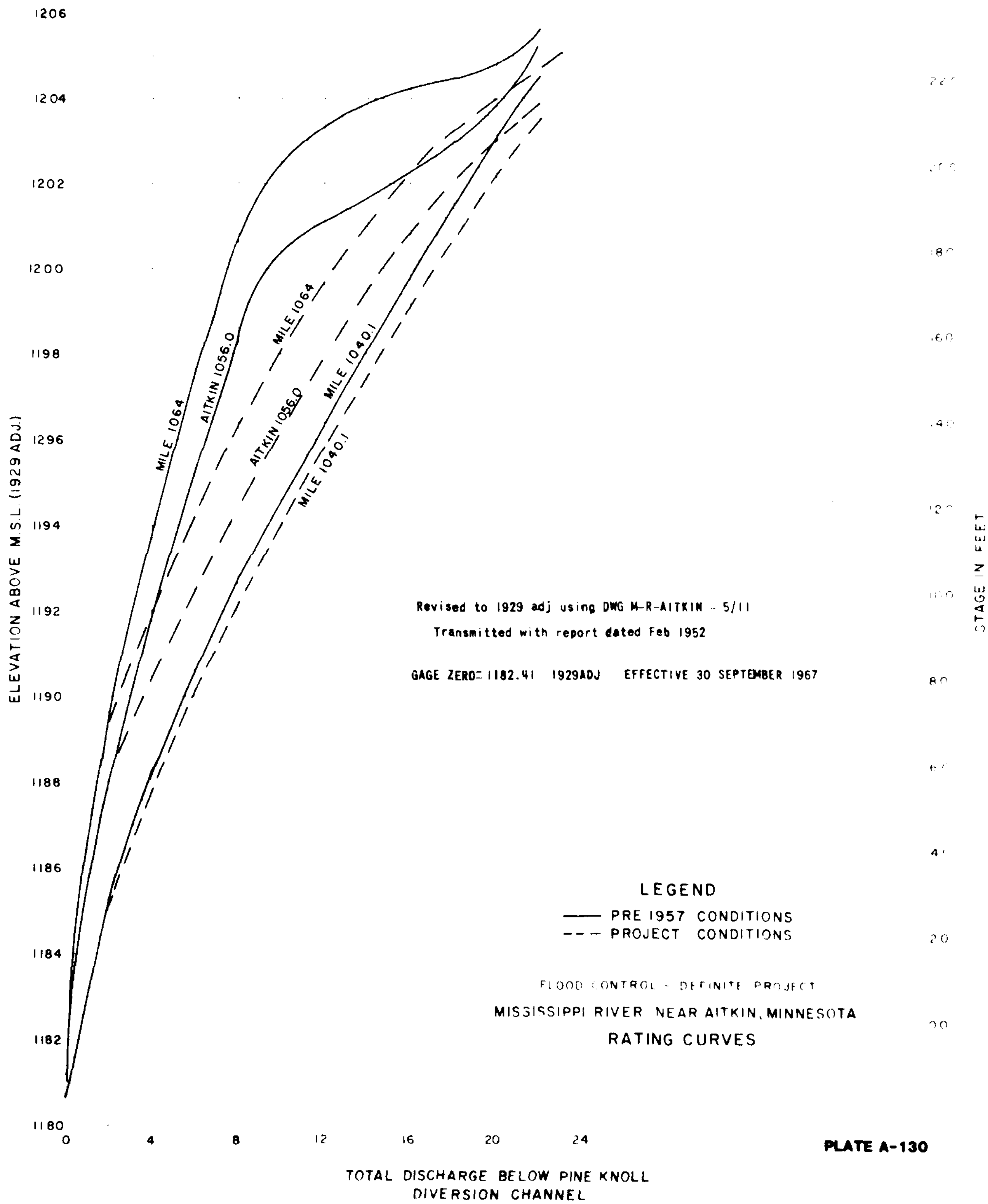
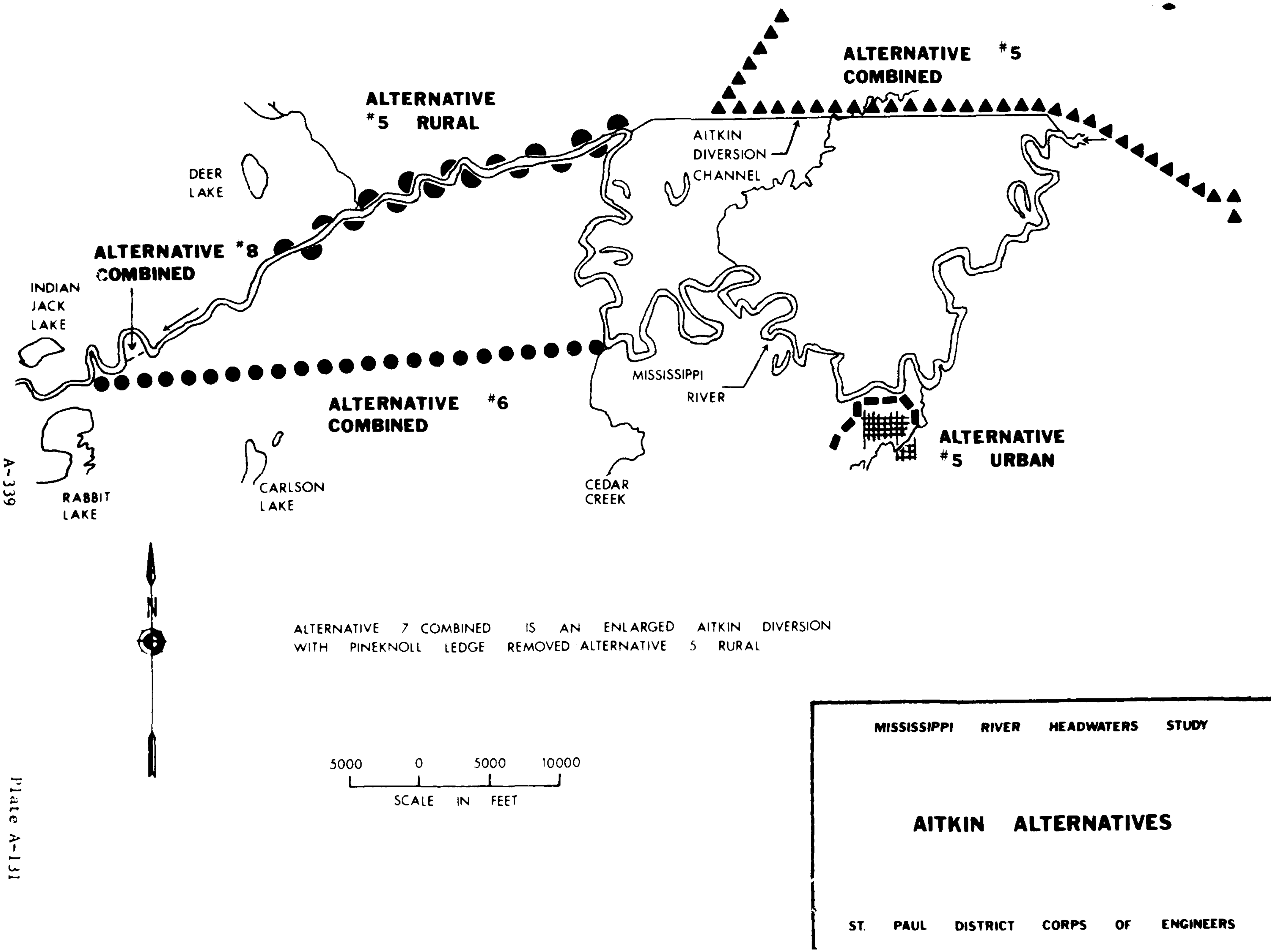
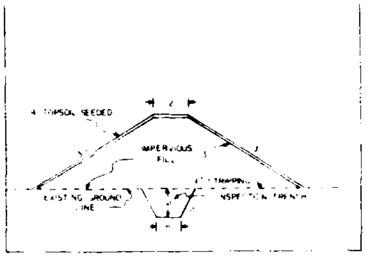

1206
1204
1202
1200
1198
1296
1194
1192
1190
1188
1186
1184
1182
1180
ELEVATION ABOVE M.S.L. (1929 ADJ.)
0
4
8
12
16
20
24
STAGE IN FEET
MILE 1064
AITKIN 1056.0
MILE 1064
AITKIN 1056.0
MILE 1040.1
MILE 1040.1
Revised to 1929 adj using DWG M-R-AITKIN - 5/11
Transmitted with report dated Feb 1952
GAGE ZERO= 1182.41 1929ADJ EFFECTIVE 30 SEPTEMBER 1967
LEGEND
PRE 1957 CONDITIONS
PROJECT CONDITIONS
FLOOD CONTROL - DEFINITE PROJECT
MISSISSIPPI RIVER NEAR AITKIN, MINNESOTA
RATING CURVES
TOTAL DISCHARGE BELOW PINE KNOLL
DIVERSION CHANNEL

PLATE A-130

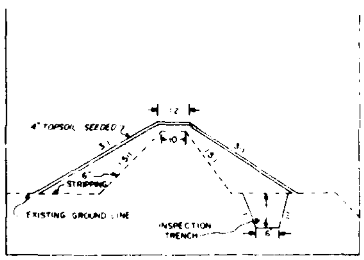


ALTERNATIVE #5
COMBINED
ALTERNATIVE
#5 RURAL
DEER
LAKE
ALTERNATIVE #8
COMBINED
INDIAN
JACK
LAKE
AITKIN
DIVERSION
CHANNEL
MISSISSIPPI
RIVER
ALTERNATIVE #6
COMBINED
ALTERNATIVE
#5 URBAN
RABBIT
LAKE
CARLSON
LAKE
CEDAR
CREEK
N
ALTERNATIVE 7 COMBINED IS AN ENLARGED AITKIN DIVERSION
WITH PINEKNOLL LEDGE REMOVED ALTERNATIVE 5 RURAL
5000 0 5000 10000
SCALE IN FEET
MISSISSIPPI RIVER HEADWATERS STUDY
AITKIN ALTERNATIVES
ST. PAUL DISTRICT CORPS OF ENGINEERS

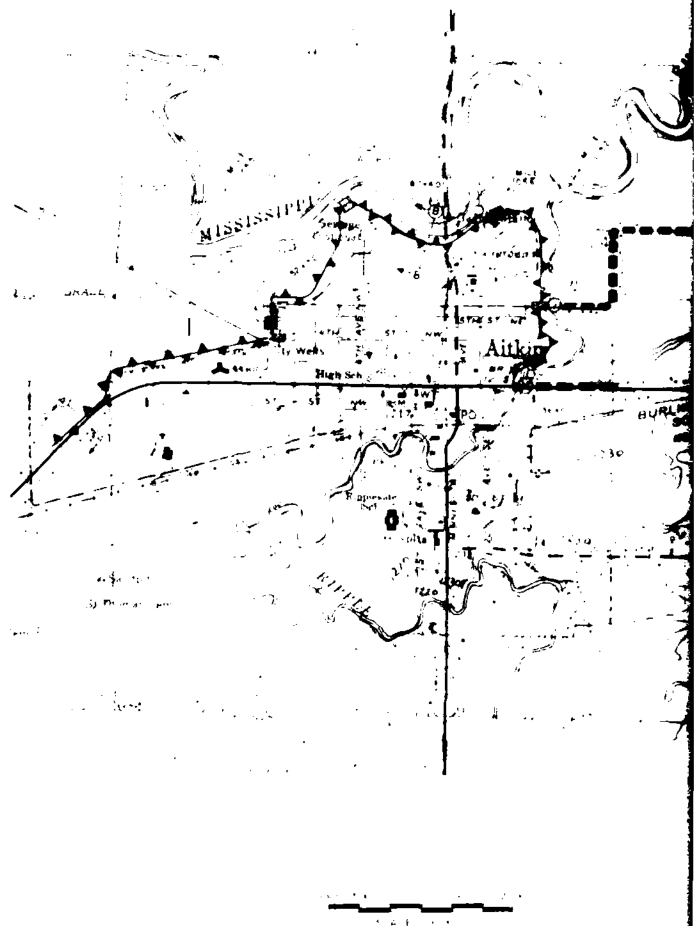
Plate A-131

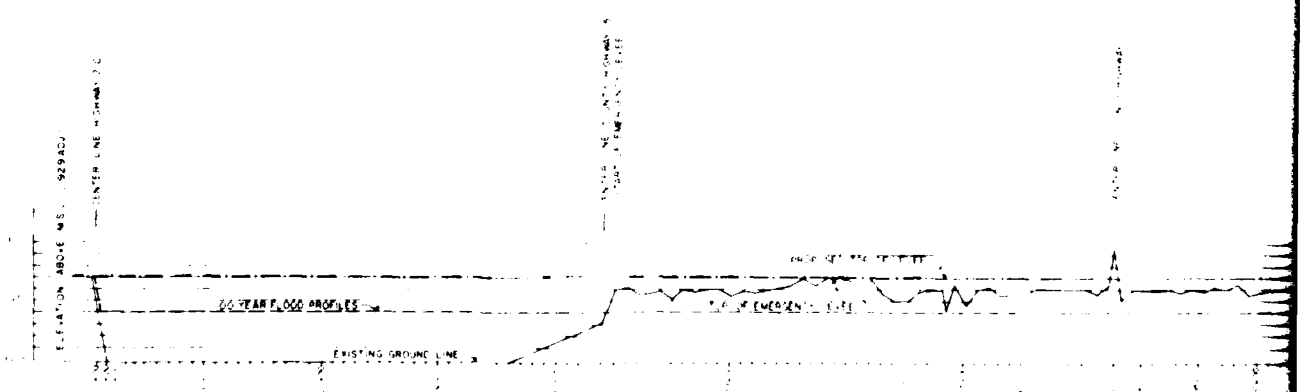


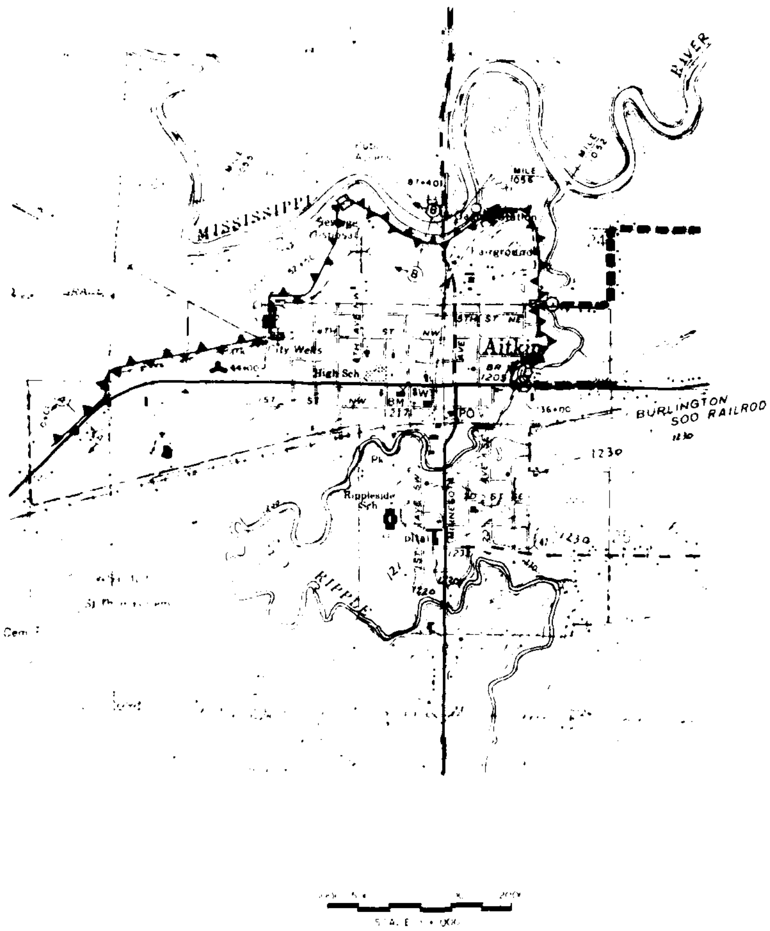
SECTION A-A
TYPICAL LEVEE SECTION
NO SCALE

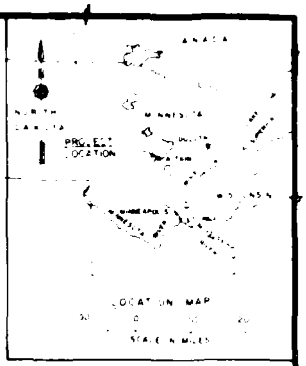


SECTION B-B
TYPICAL LEVEE SECTION
NO SCALE



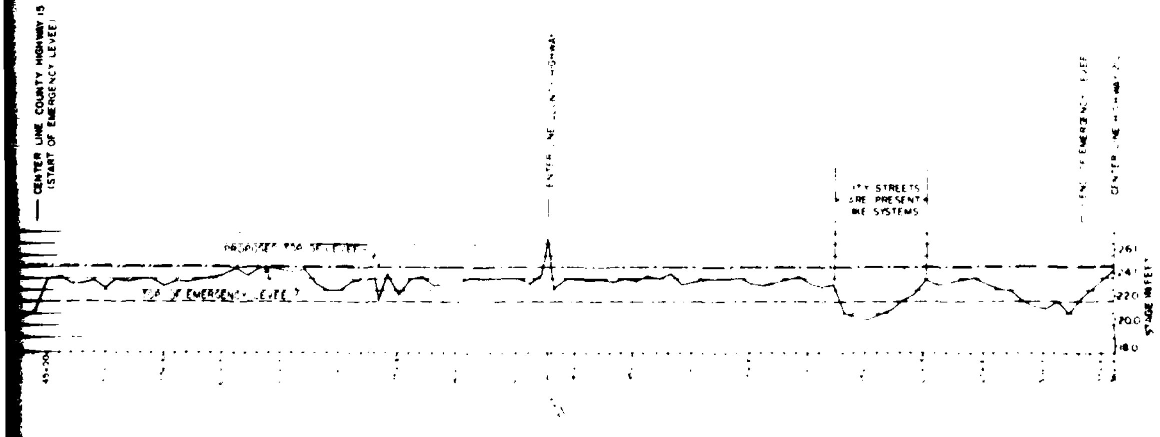






LEGEND

- PROPOSED LEVEE
- PROPOSED PUMPING STATION
- PROPOSED ROAD RAISE
- CONCRETE CULVERT
- PROPOSED GATEWELL AND GRAVITY OUTLET
- NEW SANITARY LIFT STATIONS (2)
- PROPOSED INTERIOR STORM SEWER
- BRIDGE REPLACEMENT
- BRIDGE RAISE
- RAMP



MISSISSIPPI RIVER HEADWATERS STUDY

MISSISSIPPI RIVER AT AITKIN, MINNESOTA

PROPOSED LEVEE
PLAN AND PROFILES

ST. PAUL DISTRICT CORPS OF ENGINEERS

PLATE A-132

DEPARTMENT OF THE ARMY

PLATE A-133

DEPARTMENT OF THE ARMY

PLATE

HYDROPOWER POTENTIAL OF EXISTING SIX HEADWATERS LAKES DAMS

The hydropower potential of the six Mississippi River Headwaters Lakes and the proposed Days High Landing Dam below White Oak Lake was evaluated using the following three-step procedure:

First, the potential power production of each existing dam was calculated using the following power formula:

$$P = \frac{Qhe}{11.8}$$

where

P = power production in kilowatts

Q = flow through turbine in cubic feet per second

h = hydraulic head on the turbine in feet

e = efficiency

11.8 = a constant that accounts for the weight of water, ($62.4\ lbs/ft^3$) and the rate that work is performed (1 kilowatt = 737 foot-lbs/sec

The potential power production of each of the six headwaters [illegible] and the proposed Days High Landing site was then calculated [illegible] above formula, with the following results:

Existing dam	Outflow(1) in cfs	Head(2) in feet	Power [illegible]
Winnibigoshish	520	7	[illegible]
Leech	360	[illegible]	[illegible]
Pokegama	1,160	[illegible]	[illegible]
Sandy	220	[illegible]	[illegible]
Pine	220	[illegible]	[illegible]
Gull	[illegible]	[illegible]	[illegible]
Days High Landing (proposed)	[illegible]	[illegible]	[illegible]

(1) Average [illegible]

(2) [illegible] in cfs.

(3) [illegible]

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82

5/8

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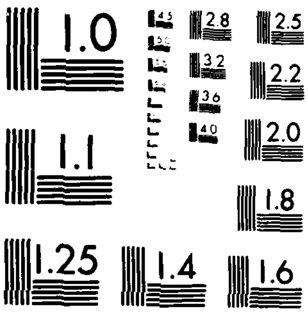


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The second step in the hydropower potential evaluation involved the determination of the total dollar value of the proposed hydropower generation at each of the six Mississippi River headwaters and the proposed Days High Landing sites. The annual dollar value per kilowatt of installed capacity was selected from a range of generalized power values provided by the Federal Energy Regulatory Commission (FERC). The total annual dollar value per kilowatt of capacity consists of two components: (1) the capacity value and (2) the energy value. The capacity value is a "benefit" for not having to construct another power plant and is based on the size or capacity of the plant. The energy value is the value of the energy that is actually generated. (This is sometimes referred to as an operations value.) The capacity and energy values provided by the FERC for a range in plant factors are as follows:

Plant capacity factor (percent)	Capacity value ($/kw/year)	Energy value (mills/kwh)	Escalated energy value (mills/kwh)	Equivalent power value (mills/kwh)
	Cycling steam plant (if varying flows are permitted, allowing peaking operation			
20	144.50	25	42	124
30	144.50	22	38	93
	Coal-fired base-load alternative			
40	135.40	20	35	74
50	135.40	20	34	65
60	135.40	19	33	59
70	135.40	19	33	55
80	135.40	19	32	51
90	135.40	19	32	49
100	135.40	18	31	46

NOTE: For Federal financing - 7 3/8 percent; October 1981 prices; 50 megawatt hydroelectric plant with entire installation dependable.

The above information was used to develop the value of potential power development at each of the seven indicated sites.

Existing site	Potential capacity (kw)	Average annual energy (Mwh)	Equivalent[1] power value (mills/kwh)	Potential power benefits $/year)
Winnibigoshish	246	1,720	67.0	115,200
Leech	171	1,200	67.0	80,400
Pokegama	354	2,480	67.0	166,200
Sandy	68	470	67.0	31,500
Pine	195	1,370	67.0	91,800
Gull	28	170	67.0	11,500
Days High Landing (proposed)[2]	394	2,760	67.0	184,900

(1) FERC power value at 50-percent plant capacity indexed to 7 5/8 percent interest rate by 7630/7381 factor.

The third step in the Mississippi River headwaters power evaluation involves determining the annualized cost of construction for including a turbine and generator in each of the proposed sites and comparing these costs with the potential benefits at each site. Cost estimate data from the National Hydropower Study (NHS) were used to estimate the total first costs in the following table.

A preliminary summary of the first cost, annual cost, and benefit-cost ratio for each of the sites is as follows:

Site	Total (1) first cost	Total (2) annual cost	Potential (3) annual power benefits	Benefit-cost ratio
Winnibigoshish	$376,000	$44,600	$115,200	2.58
Leech	660,000	66,500	80,400	1.21
Pokegama	266,000	36,200	166,200	4.59
Sandy	525,000	56,000	31,500	0.56
Pine	267,000	36,400	91,800	2.52
Gull	1,250,000	25,500	11,500	0.45
Days High Landing	3,366,000	272,000	184,900	0.68

(1) First costs in October 1981 price levels.
(2) Includes $16,000 annual operation and maintenance per site.
(3) Hydropower benefits only.

The above constitutes a preliminary analysis of the hydropower potential for the six existing Mississippi River Headwaters Lakes dams and the undeveloped Days High Landing dam. The capacity and energy values used to compute benefits are possibly too generous; actual benefits may be as much as 20 percent lower than shown. However, a detailed feasibility study would have to be conducted to confirm the advisability of developing those sites that appear economically feasible. Winnibigoshish, Pokegama, and Pine River Lakes appear feasible, in any event.

In September 1981, Maintenance Consultants, Inc., of Coon Rapids, Minnesota, a domestic corporation, applied to the Federal Energy Regulatory Commission for a preliminary permit for hydropower development at the Winnibigoshish site.

The Sandy Lake site was also included in a 1979 Department of Energy study involving small-scale hydroelectric power sites. The goal of this study was to have up to 100 rural small-scale hydroelectric projects

under construction by the end of 1981. The estimated 100 sites were to average about 3 megawatts of installed capacity each.

The sites evaluated in this study were to (1) be in a rural area, (2) have an energy potential of 100 kilowatts to 30 megawatts, and (3) have no existing hydropower. Unfortunately, the desired program objectives were not realized because of a lack of continued support and funding. The Sandy Lake site was found not economically feasible in the rural initiative study also.

STAGE 3 REPORT
MISSISSIPPI RIVER HEADWATERS LAKES STUDY

A P P E N D I X B

HISTORY OF REGULATION FOR THE MISSISSIPPI RIVER HEADWATERS LAKES

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

TABLE OF CONTENTS

TABLES

EXHIBITS

FIGURES

GENERAL

Construction of the dams at each of the six Mississippi River Headwaters Lakes was authorized by the River and Harbor Acts of 14 June 1880 and 2 August 1882. In 1888 Congress directed the Secretary of War to establish regulations governing their operation. General regulations were first established by the War Department in 1889 and later formally modified in 1931, 1935, 1936, 1944, and 1945.

The primary purpose of the six headwaters lakes dams constructed between 1884 and 1912 was for navigation at and below St. Paul, Minnesota. The area surrounding the headwaters lakes was largely undeveloped when the dams were first built and there were no serious objections to widely fluctuating lake elevations. However, area interests grew more concerned with lake operations as lakeshore development occurred for recreation and resort purposes and downstream agricultural development.

The need for water release from the six lakes for navigation was greatly reduced after completion of the 9-foot channel project locks and dams. These channel dams were constructed on the Mississippi River from the Twin Cities, Minnesota, to Alton, Illinois, during the 1930's. The Secretary of War issued new regulations for operating the six headwaters lakes during the period 1931-1945, as a result of local interest demands, reduced navigation, and related downstream water needs. The 1931-1945 War Department Regulations are still in effect for the Mississippi River Headwaters Lakes.

1889 WAR DEPARTMENT REGULATIONS

The 1889 regulations developed by the War Department were not specific as to elevations or flows. These regulations directed the Government officer in charge of dam operation to store "the surplus over the ordinary low-water supply to the reservoirs and so much of said

low-water volume as may not be immediately needed for any purpose below any dam" until the safe limits of the reservoirs were reached, or until water was needed for navigation downstream of the dams. The expressed purpose for storing water in the lakes was to provide a stable and sufficient water stage for navigation in the downstream navigable reaches of the Mississippi River and on the downstream reaches of the tributary streams on which the dams were located.

A copy of the 1889 regulations is contained in the 1896 Report of the Chief of Engineers, Volume 3, pages 1830-1831, and is as follows:

> The following rules and regulations have been adopted to control the use and administration of the reservoirs:
>
> 1. Penalties. - The river and harbor act of Congress of August 11, 1888, contains the following in relation to the reservoirs at the headwaters of the Mississippi River: "And it shall be the duty of the Secretary of War to prescribe such rules and regulations in respect to the use and administration of said reservoirs as, in his judgment, the public interest and necessity may require, which rules and regulations shall be posted in some conspicuous place or places for the information of the public. And any person knowingly and willfully violating such rules and regulations shall be liable to a fine not exceeding five hundred dollars, or imprisonment not exceeding six months, the same to be enforced by prosecution in any district court of the United States within whose territorial jurisdiction such offense may have been committed."
>
> 2. Authority of officer in charge of the reservoirs. - The accumulation of water in, and discharge of water from, the reservoirs, including that from one reservoir to another, shall be under the direction of the officer in charge of the reservoirs and of his authorized agents, subject to the following restrictions and considerations.

a. The surplus over the ordinary low-water supply to the reservoirs and so much of said low-water volume as may not be immediately needed for any purpose below any dam, shall be stored until the limit of capacity or safety of the reservoirs is reached, or until water is needed for navigation upon the streams below the dams.

b. During the season of navigation on the upper Mississippi River the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a uniform and sufficient stage of water in the navigable reaches of the Upper Mississippi and in those of any tributary thereto that may be navigated and on which a reservoir is located. The discharge may, however, at any time, be increased or diminished in order to admit of inspecting or repairing the dikes, dams, and their appurtenances.

c. Floating bodies, other than logs, may be sluiced through the reservoir dams, if their passage be deemed proper or necessary by the officer in charge. Logs may be sluiced through the said dams under the following conditions, viz:

They must be in drives of not less than 3,000,000 feet, board measure, and must be in compact shape for being rapidly sluiced so as to avoid unnecessary loss of water; and the parties having them in charge must employ a sufficient force of men to keep the sluices running full of logs, and to prevent the formation of log-jams as far above and below the dams as may be designated by the officer in charge or his

authorized agents. Drives of less than 3,000,000 feet, board measure, may be sluiced through the dams under the same conditions and requirements when the quantity is either a remnant or the total of a drive; provided, however, that there be no other drive likely to join it within forty-eight hours to make up 3,000,000 feet or more.

When all the logs that are destined to the same boom are sluiced through a reservoir dam located on a tributary of the Mississippi River, and it not being necessary, at the time of such sluicing, to draw from the reservoir for purposes of navigation, sufficient water may be liberated to allow of the rear being taken off once, so that the logs may reach the Mississippi River. If, however, a drive be delayed in reaching a reservoir dam, and through no fault or incompetency of the parties in charge of it, and, in the opinion of the officer in charge, it will not arrive before a regular period of discharge of water from the reservoir, the rear of the logs already through the dam may be taken off as before said; the rear of the delayed drive must then wait until the reservoir water is liberated for purposes of navigation.

d. Obstructions to flow of water: No person shall drive logs into a stream or pond above or below a reservoir dam when, in the opinion of the officer in charge, such act would prevent the necessary flow of water to or from such dam, or in any way injure the dam and its appurtenances, its dikes, and embankments; and should logs lying above or below a dam constitute at any time an obstruction or menace as before-said, the owners of said logs will be required to immediately remove them.

3. Handling gates. - No one, unless so authorized by the officer in charge, shall open or close any gate pertaining to the said reservoir dams, or in any way interfere with the watchmen or other Government employees at the reservoirs in the discharge of their duties. The watchmen or other employees at the dams may call for assistance from those in charge of a drive of logs when gates are to be opened, closed or maneuvered in connection with the work of sluicing said drive.

4. No one shall trespass on any reservoir dam, dike, embankment, or upon any property pertaining thereto.

Approved, February 21, 1889
Wm. C. Endicott
Secretary of War

ORIGINAL OPERATING LIMITS

Between 1889 and 1931, the six reservoirs were operated under the 1889 regulations. Although the 1889 regulations did not specify operating levels, certain operating limits were developed and used by the officer in charge. These levels, through usage, became known as "original operating limits," and were as follows:

Lake	Original operating limits in stage (feet)
Winnibigoshish	0 to 14.2
Leech	-0.5 to 5.24
Pokegama	4.5 to 12.0
Sandy	0.6 to 11.0
Pine	1.3 to 18.5
Gull	1.0 to 7.0

The lower operating limits were generally the sill elevation of the control dam or some other physical factor that limited actual releases from the dams. For example, the Leech Lake Dam is located in the Leech Lake River channel, approximately 1½ miles downstream of Leech Lake. The lake outlet provides a natural restriction on minimum releases. These lower stage limits were sometimes identified as being the "normal low-water level."

The original high stage limits were also established through usage and through engineering judgment. The high stage limits were generally set 4 feet lower than the flowage limits acquired for each reservoir area and 0.5 foot to 8.0 feet below the controlling dam height.

1931-1945 WAR DEPARTMENT REGULATIONS

The Secretary of War issued new regulations for operating the six headwaters lakes during the period 1931-1945, as a result of the demands of local interests and the reduced navigation water supply needs. The general effect of these regulations was to raise the lower lake operating limits for each lake and to lower the maximum operating limit on the Pine River chain of lakes (Whitefish Chain). The War Department's 1931-1945 regulations, which are still in effect for the Mississippi River Headwaters Lakes, are inclosed on the following exhibits 1 through 3A taken from the current lake operating manual.

REGULATIONS FOR THE USE AND ADMINISTRATION OF
THE RESERVOIRS AT HEADWATERS OF THE
MISSISSIPPI RIVER

1. Penalties. - The river and harbor act of Congress of August 11, 1888, contains the following in relation to the reservoirs at the headwaters of the Mississippi River:

"And it shall be the duty of the Secretary of War to prescribe such rules and regulations in respect to the use and administration of said reservoirs as, in his judgment, the public interest and necessity may require; which rules and regulations shall be posted in some conspicuous place or places for the information of the public. And any person knowingly and willfully violating such rules and regulations shall be liable to a fine not exceeding five hundred dollars, or imprisonment not exceeding six months, the same to be enforced by prosecution in any district court of the United States within whose territorial jurisdiction such offense may have been committed".

2. Previous Regulations now Revoked. - In accordance with the above act, the Secretary of War prescribed regulations for the use and administration of the reservoirs at the headwaters of Mississippi River under date of February 21, 1889, which are hereby revoked and the following substituted therefor.

3. Authority of Officer in Charge of the Reservoirs. - The accumulation of water in, and discharge of water from, the reservoirs, including that from one reservoir to another, shall be under the direction of the U. S. District Engineer, St. Paul, Minn., and of his authorized agents, subject to the following restrictions and considerations:

(a) Notwithstanding any other provision of these regulations, the discharge from any reservoir may be varied at any time as required to permit inspection of, or repairs to, the dams.

(b) Except as provided in subparagraph 3 (a) above, discharge from the respective reservoirs shall not be reduced below the following values, as nearly as they can be maintained:

Winnibigoshish	150	cubic feet per second
Leech Lake	100	" " " "
Pokegama	400	" " " "
Sandy Lake	10	" " " "
Pine River	10	" " " "
Gull Lake	10	" " " "

(c) During the season of navigation on the upper Mississippi River the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a sufficient stage of water in the navigable reaches of the Upper Mississippi and in those of any tributary thereto that may be navigated and on which a reservoir is located.

(d) During the transition period hereafter defined, the officer in charge shall cause discharges to be made from the reservoirs, sufficient to maintain, during the months of June, July, August and September, of each year, minimum flows in the Mississippi River at St. Paul, Minn., as follows:

June	3000	cubic	feet	per	second
July	4000	"	"	"	"
August	3500	"	"	"	"
September	2500	"	"	"	"

and in addition he shall cause such further discharges as may be necessary to fulfill the requirements of subparagraph 3 (c) above.

(e) After the transition period no discharge other than the minimum specified in subparagraph 3 (b) shall be permitted when a reservoir is at or below its minimum stage, as set forth in subparagraph 3 (i), except as may be necessary for the sluicing of logs or other floating bodies, and for the locking of boats, rafts, or logs through the dams, and excepting also such increases of discharge as may be specifically directed by the Chief of Engineers. When a reservoir is above its minimum stage, as tabulated in subparagraph 3 (i), discharges in excess of the specified minimum may be ordered by the District Engineer in accordance with these regulations.

(f) Surplus waters, not required for use in the aid of navigation, may be discharged at such time and at such rates as will result, in the judgment of the District Engineer, in the greatest general benefit. He shall consider the interests affected by fluctuating water levels of the reservoirs, as well as those affected by the discharge.

(g) During the transition period the District Engineer shall make every effort, by careful operation of the reservoirs, to maintain the reservoirs at stages as high as consistent with the requirements of these regulations.

(h) The surplus over the minimum discharges as set forth in subparagraph 3 (b) shall be stored until the limit of capacity or safety of the reservoirs is reached, or until such time as water may be discharged in accordance with these regulations.

(i) Following the transition period, the reservoirs shall be operated between the following limits, referred to the zeros of the Government gages in the lakes, in so far as the water levels reasonably can be controlled by the District Engineer and in so far as such limits can be maintained under the requirements of paragraph 3 of these regulations:

Winnibigoshish	from	6.0 to 14.2
Leech Lake	"	1.0 to 5.24
Pokegama	"	6.0 to 12.0
Sandy Lake	"	7.0 to 11.0
Pine River	"	9.0 to 15.0
Gull Lake	"	5.0 to 7.0

4. Transition Period. - The period, commencing with the date of approval of these regulations and extending to the January 1st following, on which a total volume of 10 billion cubic feet of water shall be available in the reservoirs above the minimum stages as set forth in subparagraph 3 (i), is hereafter termed the transition period.

5. Passage of Logs and Other Floating Bodies. - Logs and other floating bodies may be sluiced or locked through the dams, but prior authority for the sluicing of logs must be obtained from the District Engineer when this operation necessitates a change of discharge.

6. Obstructions to Flow of Water. - No person shall place floating bodies in a stream or pond above or below a reservoir dam when, in the opinion of the officer in charge, such act would prevent the necessary flow of water to or from such dam, or in any way injure the dam and its appurtenances, its dikes, and embankments; and should floating bodies lying above or below a dam constitute at any time an obstruction or menace as beforesaid, the owners of said floating bodies will be required to remove them immediately.

7. Trespass. - No one shall trespass on any reservoir dam, dike, embankment, or upon any property pertaining thereto.

Approved February 11, 1931

Patrick J. Hurley

Secretary of War

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON

7245(Miss.R.Reservoirs)25 April 1st, 1931

Honorable Harold Knutson,
Representative in Congress
St. Cloud, Minn.

My dear Mr. Knutson:

1. Reference is made to the question of modifying the regulations for the reservoirs at the headwaters of the Mississippi River, with particular reference to Pine River and Pokegama, as discussed in our conference of February 26th. The regulations as approved by the Secretary of War, February 11, 1931, provide for a minimum level at Pine River reservoir of 9 feet and a maximum level for Pokegama of 12 feet. Your request that the minimum level at Pine River be increased to 11 feet and the maximum level at Pokegama be reduced to 10 feet has received careful consideration.

2. The District Engineer at St. Paul will be instructed to establish a minimum level of 11 feet instead of 9 feet at Pine River reservoir as speedily as is practicable under the regulations. He will be further instructed that additional water under paragraph 3 (c) of the regulations will not be released for navigation without the approval of this office.

3. It has been determined that reduction in the upper level of Pokegama from 12 feet to 10 feet would make impossible the maintenance of the minimum discharges prescribed in paragraph 3 (b) and 3 (d) of the regulations, Pokegama being the key of the reservoir system. A change in the regulations at Pokegama is therefore considered impracticable at this time.

4. The matter of further change in the regulations will be taken up after one season's experience.

Very truly yours,

(Signed) LYTLE BROWN

Lytle Brown
Major General
Chief of Engineers

Exhibit 1-A

REGULATIONS FOR THE USE AND ADMINISTRATION OF
THE RESERVOIRS AT HEADWATERS OF THE
MISSISSIPPI RIVER

1. Penalties. - The river and harbor act of Congress of August 11, 1888, contains the following in relation to the reservoirs at the headwaters of the Mississippi River:

"And it shall be the duty of the Secretary of War to prescribe such rules and regulations in respect to the use and administration of said reservoirs as, in his judgment, the public interest and necessity may require; which rules and regulations shall be posted in some conspicuous place or places for the information of the public. And any person knowingly and willfully violating such rules and regulations shall be liable to a fine not exceeding five hundred dollars, or imprisonment not exceeding six months, the same to be enforced by prosecution in any district court of the United States within whose territorial jurisdiction such offense may have been committed".

2. Previous Regulations now Revoked. - In accordance with the above act, the Secretary of War prescribed regulations for the use and administration of the reservoirs at the headwaters of Mississippi River under date of February 21, 1889, which are hereby revoked and the following substituted therefor.

3. Authority of Officer in Charge of the Reservoirs. - The accumulation of water in, and discharge of water from, the reservoirs, including that from one reservoir to another, shall be under the direction of the U. S. District Engineer, St. Paul, Minn., and of his authorized agents, subject to the following restrictions and considerations:

(a) Notwithstanding any other provision of these regulations, the discharge from any reservoir may be varied at any time as required to permit inspection of, or repairs to, the dams, dikes, of their appurtenances, or to prevent damage to lands or structures above or below the dams.

(b) Except as provided in subparagraph 3(a) above, discharge from the respective reservoirs shall not be reduced below the following average annual values, as nearly as they can practically be maintained:

Pokegama	200 cubic feet per second
Sandy Lake	10 " " " "
Pine River	10 " " " "
Gull Lake	10 " " " "

(c) During the season of navigation on the upper Mississippi River, the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a sufficient stage of water in the navigable reaches of the Upper Mississippi and in those of any tributary thereto that may be navigated and on which a reservoir is located.

(d) During the transition period hereafter defined, the officer in charge shall cause discharges to be made from the reservoirs, in addition to the minimum specified above, sufficient to maintain, at St. Paul, as nearly as practicable, the computed natural discharge, based upon all available rainfall data, for the months of June, July, August and September, but not to exceed the following:

June	3,000	cubic	feet	per	second
July	4,000	"	"	"	"
August	3,500	"	"	"	"
September	2,500	"	"	"	"

except that he shall cause such further discharges as may be necessary to fulfill the requirements of subparagraph 3(c) above.

(e) After the transition period no discharge other than the minimum specified in subparagraph 3(b) shall be permitted when a reservoir is at or below its minimum stage, as set forth in subparagraph 3(i), except as may be necessary for the sluicing of logs or other floating bodies, and for the locking of boats, rafts, or logs through the dams, and excepting also such increases of discharge as may be specifically directed by the Chief of Engineers. When a reservoir is above its minimum stage, as tabulated in subparagraph 3(i), discharges in excess of the specified minimums may be ordered by the District Engineer in accordance with these regulations.

(f) Surplus waters, not required for use in the aid of navigation, may be discharged at such time and at such rates as will result, in the judgment of the District Engineer, in the greatest general benefit. He shall consider the interests affected by fluctuating water levels of the reservoirs, as well as those affected by the discharge.

(g) During the transition period the District Engineer shall make every effort, by careful operation of the reservoirs, to maintain the reservoirs at stages as high as consistent with the requirements of these regulations.

(h) The surplus over the minimum discharges as set forth in subparagraph 3(b) shall be stored until the limit of capacity or safety of the reservoirs is reached, or until such time as water may be discharged in accordance with these regulations.

(i) Following the transition period, the reservoirs shall be operated between the following limits, referred to the zeros of the Government gages in the lakes, insofar as the water levels reasonably can be controlled by the District Engineer, and insofar as such limits can be maintained under the requirements of paragraph 3 of these regulations:

Winnibigoshish	from 6.0 to 14.2
Leech Lake	" 1.0 to 5.24
Pokegama	" 6.0 to 12.0
Sandy Lake	" 7.0 to 11.0
Pine River	" 9.0 to 15.0
Gull Lake	" 5.0 to 7.0

The range of fluctuations in levels in any reservoir in a single calendar year shall be held at a minimum consistent with the requirements of these regulations and with the inflow of that year.

4. Transition Period. - The period, commencing with the date of approval of these regulations and extending to the January 1st following, on which a total volume of 10 billion cubic feet of water shall be available in the reservoirs above the minimum stages as set forth in subparagraph 3(i), is hereafter termed the transition period.

5. Passage of Logs and Other Floating Bodies. - Logs and other floating bodies may be sluiced or locked through the dams, but prior authority for the sluicing of logs must be obtained from the District Engineer when this operation necessitates a change of discharge.

6. Obstructions to Flow of Water. - No person shall place floating bodies in a stream or pond above or below a reservoir dam when, in the opinion of the officer in charge, such act would prevent the necessary flow of water to or from such dam, or in any way injure the dam and its appurtenances, its dikes, and embankments; and should floating bodies lying above or below a dam consitute at any time an obstruction or menace as beforesaid, the owners of said floating bodies will be required to remove them immediately.

7. Trespass. - No one shall trespass on any reservoir dam, dike embankment or upon any property pertaining thereto.

Approved, May 14th, 1935
Harry H. Woodring,
Acting Secretary of War

REGULATIONS FOR THE USE AND ADMINISTRATION OF THE RESERVOIRS AT HEADWATERS OF THE MISSISSIPPI RIVER

- -

RESERVOIRS AT HEADWATERS OF THE MISSISSIPPI RIVER

1. The Reservoirs at the Headwaters of the Mississippi River include Winnibigoshish, Leech Lake, Pokegama, Sandy Lake, Pine River and Gull Lake.

2. Penalties. The river and harbor act approved August 11, 1888, includes the following provisions as to the administration of the headwaters reservoirs:

> "And it shall be the duty of the Secretary of War to prescribe such rules and regulations in respect to the use and administration of said reservoirs as, in his judgment, the public interest and necessity may require; which rules and regulations shall be posted in some conspicuous place or places for the information of the public. And any person knowingly and willfully violating such rules and regulations shall be liable to a fine not exceeding five hundred dollars, or imprisonment not exceeding six months, the same to be enforced by prosecution in any district court of the United States within whose territorial jurisdiction such offense may have been committed."

3. Previous Regulations Now Revoked. In accordance with the above act, the Secretary of War prescribed regulations for the use and administration of the reservoirs at the headwaters of Mississippi River under date of February 11, 1931, which together with all subsequent amendments are hereby revoked and the following substituted therefor.

4. Authority of Officer in Charge of the Reservoirs. The accumulation of water in, and discharge of water from the reservoirs, including that from one reservoir to another, shall be under the direction of the U. S. District Engineer, St. Paul, Minnesota, and of his authorized agents subject to the following restrictions and considerations:

a. Notwithstanding any other provision of these regulations, the discharge from any reservoir may be varied at any time as required to permit inspection of, or repairs to, the dams, dikes or their appurtenances, or to prevent damage to lands or structures above or below the dams.

b. Except as provided in subparagraph 4(a) above, the average annual discharge from the respective reservoirs shall not be reduced below the following values, as nearly as they can practically be maintained:

Winnibigoshish	150	cubic	feet	per	second
Leech Lake	70	"	"	"	"
Pokegama	200	"	"	"	"
Sandy Lake	80	"	"	"	"
Pine River	90	"	"	"	"
Gull Lake	30	"	"	"	"

c. During the season of navigation on the upper Mississippi River, the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a sufficient stage of water in the navigable reaches of the Upper Mississippi and in those of any tributary thereto that may be navigated and on which a reservoir is located.

d. Surplus waters in storage above the stages listed in paragraph 4(g), not required for use in the aid of navigation, as provided for in subparagraph 4(c) above, may be discharged at such time and at such rates as will result, in the judgment of the District Engineer, in the greatest general benefit or the minimum of injuries to all affected interests.

e. No discharge other than the minimum specified in subparagraph 4(b), shall be permitted when a reservoir is at or below its minimum stage as set forth in subparagraph 4(g), except such increased of discharge as may specifically be directed by the Chief of Engineers.

f. The surplus inflow over the minimum discharge set forth in subparagraph 4(b), shall be stored until the limit of capacity or safety of the reservoir is reached, or until such time as water may be discharged in accordance with these regulations.

g. So far as practicable, under the requirements of these regulations, the officer in charge will cause the reservoirs to be maintained above the following minimum stages, referred to zeros of respective Government gauges:

Winnibigoshish	6.0
Leech Lake	1.0
Pokegama	6.0
Sandy Lake	7.0
Pine River	9.0
Gull Lake	5.0

The range of fluctuations in levels in any reservoir in a single calendar year shall be held at a minimum consistent with the requirements of these regulations and with the inflow of that year. If, through necessity reservoirs are drawn below these stages, minimum stages will be restored at the first practicable opportunity.

5. Passage of Logs and Other Floating Bodies. Logs and other floating bodies may be sluiced or locked through the dams, but prior authority for the sluicing of logs must be obtained from the District Engineer when this operation necessitates a material change in discharge.

6. Obstructions to Flow of Water. No person shall place floating bodies in a stream or pond above or below a reservoir dam when, in the opinion of the officer in charge, such act would prevent the necessary flow of water to or from such dam, or in any way injure the dam and its appurtenances, its dikes and embankments; and should floating bodies lying above or below a dam constitute at any time an obstruction or menace as aforesaid, the owners of said floating bodies will be required to remove them immediately.

7. Trespass. No one shall trespass on any reservoir dam, dike, embankment or upon any property pertaining thereto.

Approved, February 4, 193[illegible],
Geo. H. Dern, Secretary of War

COPY

WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
1217 U. S. Post Office and Custom House
St. Paul 1, Minn.

25 January 1945

To Whom it May Concern:

The Regulations to govern the operation of the Reservoirs at the headwaters of the Mississippi River, approved by the Secretary of War 4 February 1936, have been revised by the Secretary of War in accordance with the copy of the amendment printed below and on the back of this notice.

The only effect of this amendment is to reduce the minimum operating level of Leech Lake Reservoir from 1.0 to 0.0 stage.

This action was taken on the request of a number of property owners at a meeting at Walker, Minnesota, on 25 October 1944.

/s/H. J. MANGER
H. J. MANGER
Major, Corps of Engineers
Acting District Engineer

NAVIGATION REGULATIONS

Pursuant to Section 1 of the River and Harbor Act of August 11, 1888 (25 Stat. 419; 33 U.S.C. 601), the provisions of Section 207.340 are hereby modified to provide for a change in the minimum stage of Leech Lake Reservoir from 1.0 to 0.0 feet, subparagraph (d) (7) being amended to read as follows:

207.340 Reservoirs at headwaters of the Mississippi River; use and administration. Amendment.

* * * * * * *

(over)

(7) So far as practicable, under the requirements of these regulations, the officer in charge will cause the reservoirs to be maintained above the following minimum stages, referred to zeros of respective Government gauges:

Winnibigoshish,	6.0
Leech Lake,	0.0
Pokegama,	6.0
Sandy Lake,	7.0
Pine River,	9.0
Gull Lake,	5.0

The range of fluctuations in levels in any reservoir in a single calendar year shall be held at a minimum consistent with the requirements of these regulations and with the inflow of that year. If, through necessity reservoirs are drawn below these stages, minimum stages will be restored at the first practicable opportunity.

* * * * * * *

Approved December 29, 1944

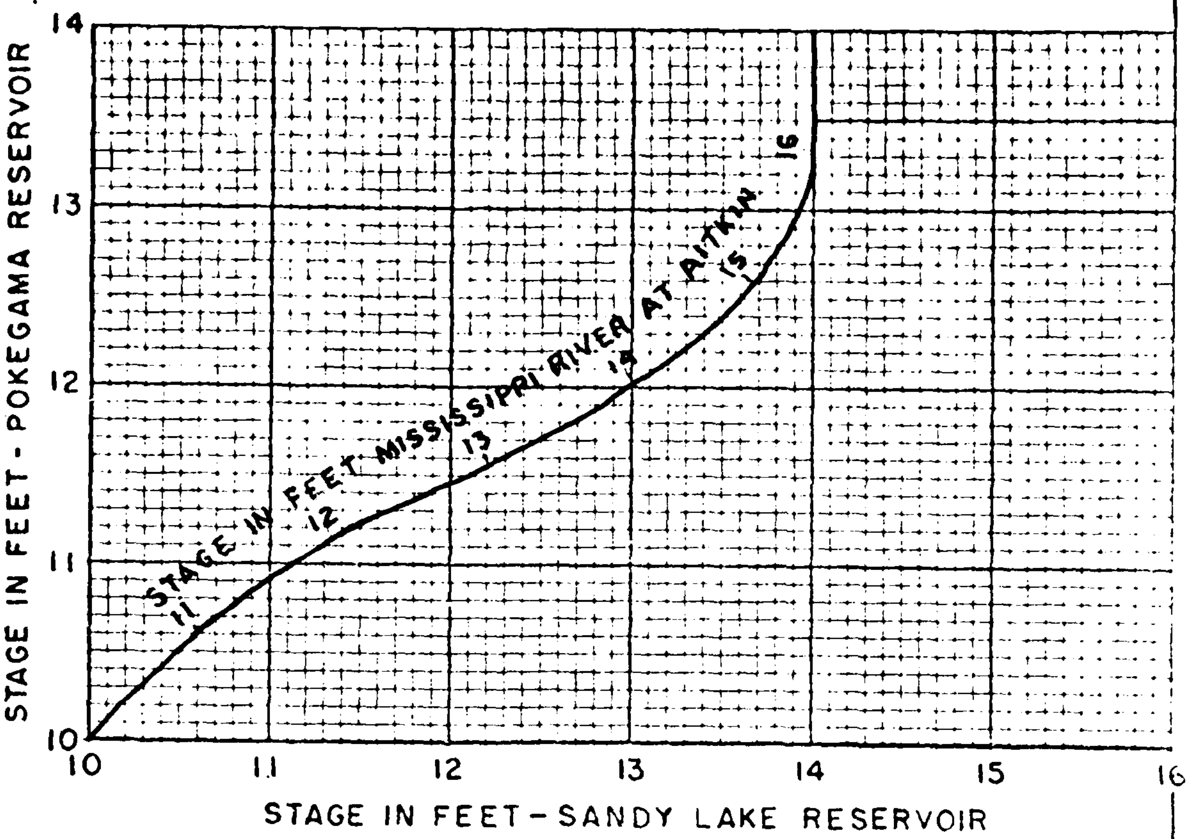
/s/ Henry L. Stimson
Secretary of War

"Note: These rules and regulations, when published, have the force of law. They were published in the Federal Register on 10 January 1945; public notices of their approval were sent to all known interested parties on 25 January 1945; and they have been posted in the post offices at Walker, Cass Lake, Wilkinson, Federal Dam, Bena and Boy River, Minnesota."

1956 TENTATIVE GUIDE CURVES FOR SPRING AND SUMMER FLOODS (POKEGAMA-SANDY-AITKIN)

The operation of the headwaters lakes continued to generate much controversy over the years and many meetings were held with local groups to determine possible modifications in lake operating procedures that would be acceptable to all concerned. One of these modifications resulted from a 3 December 1953 meeting with Pokegama and Sandy Lakes and Aitkin, Minnesota, area interests. Tentative guide curves were developed to minimize total damage in the three areas with the operation of the headwaters lakes.

The tentative curves were revised slightly in 1956 to eliminate storing water in Pokegama Lake after floods had peaked in downstream Aitkin. The 1956 curves were formalized in the 1963 Operating Plan Manual and are shown on the following figures.



NOTE:

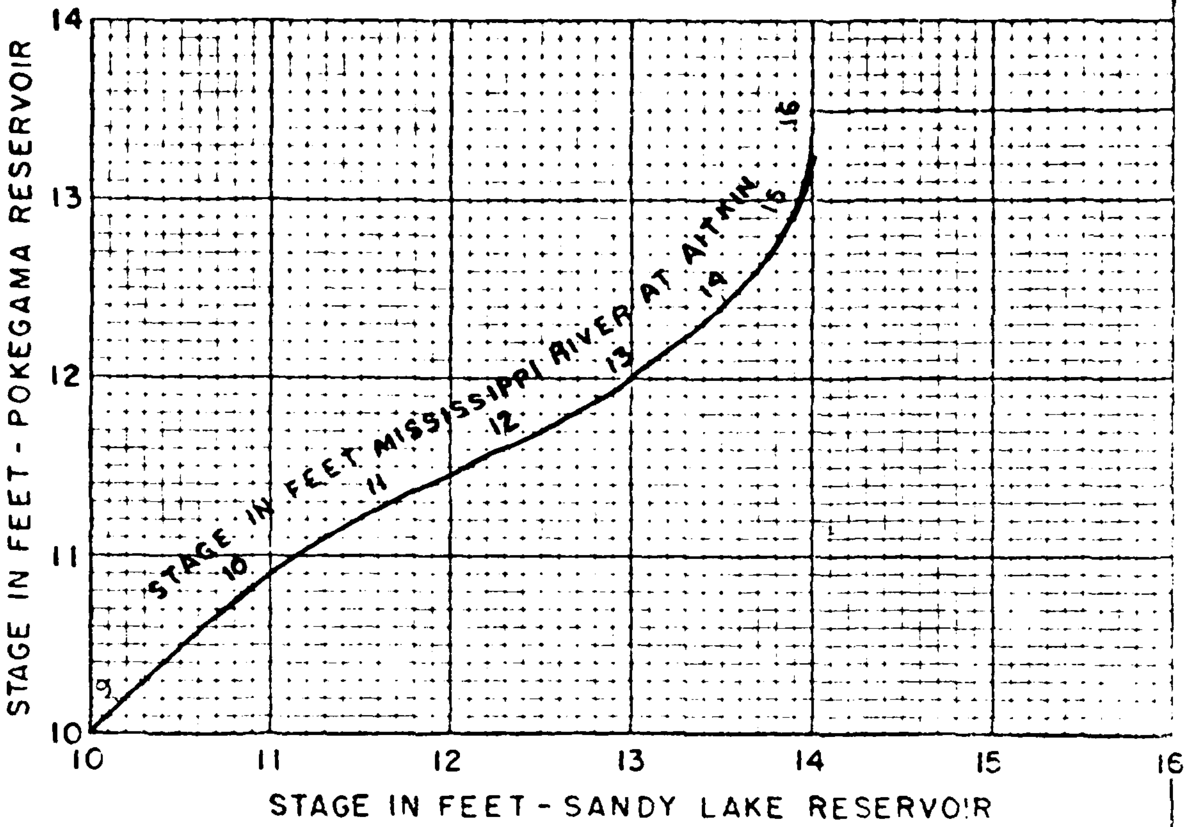
Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

Pokegama Gage Zero = 1264.42
Sandy Gage Zero = 1207.31
Aitkin Gage Zero = 1185.41

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAMS AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL

TENTATIVE GUIDE CURVE
SPRING FLOODS (MAR.-15 MAY)

CORPS OF ENGINEERS U S ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINNESOTA
APRIL 1963



NOTE

Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

Pokegama Gage Zero = 1264.42
Sandy Gage Zero = 1207.31
Aitkin Gage Zero = 1185.41

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAMS AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL

TENTATIVE GUIDE CURVE
SUMMER FLOODS (15 MAY - SEPT.)

CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINNESOTA
APRIL 1963

1961-1963 STATE OF MINNESOTA RECOMMENDATIONS FOR REGULATION

GENERAL

The State of Minnesota made a comprehensive study and recommendations for operating the six Mississippi River Headwaters Lakes culminating in 1963. These State recommendations were never formally adopted but, in actual practice, the recommended minimum flow releases for fish and wildlife and other purposes are followed during low-flow periods. These minimum releases are contained in the Commissioner of Conservation's 19 April 1963 order. (See page B-23.)

BACKGROUND

Several hearings were held between 1940 and 1945 to gather testimony concerning the operation of the dams. This testimony revealed that no thorough studies had been made to determine water levels which should be established to best serve the needs of the users of the lakes and waters.

The Minnesota Legislature appointed an Interim Commission in 1957 to study control of the headwaters dams. After hearings with many people, including the St. Paul District, Corps of Engineers, the Interim Commission concluded that the dams of the Mississippi Headwaters would be best controlled if responsibilities for operation were shared by the Corps of Engineers and the State of Minnesota. This recommendation was accepted by the 1959 Legislature and a second Interim Commission was appointed to "consider effectuating joint control between the State and Federal authorities of the Upper Mississippi Reservoirs in the interest of the people of the State . . ." The State Commissioner of Conservation was also authorized to enter into temporary agreements with the Corps of Engineers for joint control, upon approval of the Interim Commission.

Negotiations between the St. Paul District, Corps of Engineers and the Interim Commission were initiated and proceeded through draft of a tentative agreement. In 1960 the St. Paul District reported that the Corps had no authority to execute the proposed agreement without further congressional direction. Funds were subsequently allocated to make a thorough study of the Upper Mississippi River, originally authorized in 1945, as a basis for a report to the Secretary of the Army and to Congress on what Federal action might be most appropriate. This study was never completed for lack of funds.

The Minnesota Legislature, at its 1961 session, enacted a State law stating that "The Commissioner of Conservation is authorized and directed to enter into Cooperative Agreements with the United States of America, acting through the Department of the Army, for the joint control and regulation of these reservoirs within the principles hereinafter prescribed so as to effectuate control of the water elevations and the water discharges from these lakes in the interests of the State of Minnesota, subject only to any paramount need of waters from these sources in aid of any substantial navigation requirements, and subject further to any substantial requirement of providing necessary flood control storage capacity as determined by the Corps of Army Engineers." The law also authorizes and directs the Commissioner of Conservation to formulate a plan for the operation of the dams and provides guidelines for such a plan to assure full consideration of all interests in the Mississippi River Headwaters, both in the area and downstream. The Commissioner of Conservation issued an order dated 19 April 1963, in response to the 1961 session laws authorizing him to do so.

No formal agreement was made between the Corps of Engineers and the State of Minnesota concerning joint control and regulation of the six Mississippi River Headwaters Lakes. However, in actual practice, the St. Paul District attempts to coordinate lake operation in conformance with the 1963 Commissioner's order whenever possible, especially for low flows. The low-flow limitations in table D of the 1963 order are followed in detail by the St. Paul District.

COMMISSIONER'S ORDER

Copies of the 19 April 1963 Commissioner's Order, the 1961 Session Laws, and recommended operating plans for Winnibigoshish and Leech Lakes follow:

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION

In the Matter of the Adoption of a plan by the Commissioner of Conservation for the operation of the dams controlling each of the following named headwater lakes of the Mississippi River: Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine River (the Whitefish Chain), Sandy Lake, and Gull Lake.	FINDINGS OF FACT CONCLUSIONS O R D E R

- - - - - - - - -

The above entitled matter came on for hearing before Clarence Prout, Commissioner of Conservation in the Courthouse of the City of Brainerd, Minnesota, on Wednesday, November 14, 1962, at 10:00 a.m. and at a continuation thereof in the Centennial Office Building, St. Paul, Minnesota, on Wednesday, December 19, 1962, at 10:00 a.m., upon notice duly published pursuant to Minnesota Statutes 1961, Section 110.51. The purpose of said hearing was to determine whether or not a plan formulated by the Commissioner of Conservation pursuant to Minnesota Statutes 1961, Sections 110.47 through 110.53 shall be put into effect for the operation of dams controlling the above named headwater lakes and reservoirs of the Mississippi River.

The Commissioner was represented at the hearing by Mr. Frank J. Murray, Deputy Attorney General and Lawrence J. Vaubel, Special Assistant Attorney General in behalf of Walter F. Mondale, Attorney General.

After public presentation of said plan and hearing all parties interested therein, and after due consideration of the evidence received at said hearing, the Commissioner of Conservation makes the following:

FINDINGS OF FACT

I

Dams have been built by the government of the United States at the outlets of Winnibigoshish, Leech, Pokegama, Sandy, Cross and Gull Lakes in northern Minnesota to create reservoirs known as Winnibigoshish, Leech, Pokegama, Sandy, Pine River and Gull Reservoirs, respectively. These reservoirs provided water used to augment flows in the Mississippi River as an aid to navigation during periods of low natural flow. The reservoir area, watershed area, reservoir capacity and year of original completion for each reservoir is as follows:

Reservoir	Year of Completion	Reservoir Area Square Miles	Watershed Area Square Mi.	Reservoir Capacity Billion Cu. Ft.
Winnibigoshish	1884	179	1,442	42
Leech	1884	250	1,163	32
Pokegama	1884	35	660*	5
Sandy	1895	16	421	3
Pine River	1886	23	562	7
Gull	1913	20	287	3

*Exclusive of area controlled by Winnibigoshish and Leech Dams, which are tributary to Pokegama Reservoir.

II

The original dams at the outlets of Winnibigoshish, Leech, Pokegama, Sandy and Pine River Reservoirs have been reconstructed by the government of the United States. The present dams were built in 1900, 1902, 1904, 1909 and 1907, respectively. The dams have been maintained, modified, and operated by the United States Army, Corps of Engineers, since construction.

III

The government of the United States owns all interests in lands needed for operation of the reservoirs.

IV

The operation of Winnibigoshish Reservoir has been modified by the construction of the United States Department of Agriculture, Forest Service, of the dam known as Knutson dam at the outlet of Cass Lake within the flowage area of Winnibigoshish Reservoir. This dam was constructed in 1928 and has been operated since by the Forest Service. Its operation normally maintains Cass Lake and its tributaries at a higher elevation than Winnibigoshish, for the purpose of providing desirable levels in Cass Lake and along its shore.

V

The Mississippi River for some distance below Winnibigoshish Reservoir, and the Leech Lake River below Leech Reservoir, have been improved by the government of the United States, and easements along these streams have been acquired, so that water may be released from these reservoirs in greater quantities without causing overbank flow than could be released when the streams were in their natural condition. The easements also entitle the government to discharge water from those reservoirs in excess of the capacities of the channels downstream, within the limits of the easements.

VI

Since completion of the above named reservoirs, a series of locks and dams has been completed by the government of the United States in the Mississippi River below St. Anthony Falls in Minneapolis so that the need for the release of water from these reservoirs to maintain navigable depth in the Mississippi at Minneapolis and farther downstream is greatly reduced. The limited navigation on the Mississippi above Minneapolis that was formerly benefited by release of reservoir water has now disappeared so that the need to release water for this upper river navigation no longer exists. A navigation lock is under construction by the government of the United States at St. Anthony Falls, and will soon be completed, so that large river craft will be able to navigate the Mississippi River above St. Anthony Falls within the corporate limits of the City of Minneapolis. It is possible that release of water from the reservoirs may be needed in the future to operate the locks at St. Anthony Falls and farther downstream and to aid navigation in other ways.

VII

The dams at the outlet of the reservoirs have been operated by the Corps of Engineers to reduce flooding along the Mississippi, Leech Lake, Sandy, Gull and Pine Rivers. The need for flood storage in the reservoirs to decrease flood flows in the Mississippi River at Aitkin has been reduced by construction of a diversion channel near Aitkin. Nevertheless, the need remains for regulation of reservoir levels and discharges so as to minimize flooding, insofar as practicable.

VIII

Flow of water in the Leech Lake River below Leech Reservoir has been modified by construction of a dam in the river at the outlet of Mud and Goose Lakes. The dam was originally built and has been reconstructed in recent years by the Minnesota Department of Conservation. The dam maintains desirable water levels for game and fish and wildlife resources and reduces the adverse effect on these resources of variations in the rate of release of water from Leech Reservoir.

IX

Water is obtained from the Mississippi River for municipal water supply and for distribution to suburbs by the cities of Minneapolis and St. Paul. Normally, the river flow is adequate for municipal water supply for these cities. River discharge at the St. Paul water system intake on the Mississippi River at Fridley has fallen as low as 586 cubic feet per second. It is estimated that by 1980 a minimum flow of 660 cubic feet per second in the Mississippi River at the Minneapolis water intake will be necessary to supply the needs of Minneapolis and the suburbs that obtain their water from Minneapolis. Needs of the City of St. Paul and operating requirements of the lock and dam at St. Anthony Falls, will necessitate a minimum flow at this point of 1,000 cubic feet per second.

X

Water is obtained from the Mississippi River for municipal water supply by the City of St. Cloud. It is probable that river flow will continue to be sufficient for the needs of this municipality.

XI

All Minnesota municipalities located along the Mississippi River and having municipal sewage disposal facilities discharge sewage treatment plant effluent or untreated sewage into the Mississippi River. The most populous of these municipalities are Minneapolis and St. Paul and their suburbs. Studies made by the Minneapolis-St. Paul Sanitary district show that with probable population increases in the urban area served by the district it will not be possible at all times to maintain the river in satisfactory sanitary condition below the sewage treatment plant outlet without augmentation of low river flows, even if there is the best possible treatment of the sewage. River flows required for satisfactory sanitary conditions in the river need not be as great at the less populous municipalities but there may be occasions when increased dilution of sewage disposal system effluent will be desirable.

XII

Water power is developed at several locations along the Mississippi River below the reservoirs. Water power is valuable for the production of paper by the Blandin Paper Company at Grand Rapids. The power production facilities at this plant are capable of utilizing up to 1,700 cubic feet per second in the production of water power. Other power plants are located at Little Falls, Royalton, Sartell, Coon Rapids, St. Anthony Falls, and St. Paul. These plants all benefit from reliable streamflow.

XIII

Mississippi River water is used at several locations for condenser cooling water by steam-electric power producers. The Minnesota Power and Light Company desires the maintenance of a minimum stage of 6.0 for its Clay Boswell plant located on Pokegama Reservoir, and a minimum discharge of 200 cubic feet per second through Pokegama dam. Mississippi River water is used for condenser cooling water at four steam-electric generating plants in the Twin Cities area.

XIV

The reservoirs and the reservoir shores are used by many people for recreational activities including fishing, boating, camping and picnicking. There are numerous resorts, cottages and homes along the shores. This use of the reservoirs has a very substantial effect on the economy of this region of Minnesota.

XV

Production of game, fish and wild rice along the Mississippi and Leech Lake Rivers upstream from Pokegama Reservoir is affected by the release of water from Winnibigoshish and Leech Reservoirs, through the effect of such release on the stage of the rivers downstream from the reservoirs. Heavy release causes the drowning out of muskrat houses, winter habitat and feed supply, and variation in river stage may cause the destruction of wild rice plants.

XVI

There is a substantial commercial production of wild rice in the reservoirs. This production may be adversely affected by variations in reservoir stage.

XVII

The shorelines of Leech and Winnibigoshish Reservoirs are composed of erodible soil and have been damaged by wind-driven waves, necessitating the construction of shore protection works.

XVIII

The operation of the reservoirs has been modified from time to time by the Corps of Engineers in recognition of the diminished needs for release of water for navigation, and in recognition of the increased importance of recreation, game and fish production, and wild rice production. The present plan of operation, which has been in effect for many years, provides for the following ranges of levels:

Reservoir	Ordinary Stage Limits, Present Operation	Ordinary Summer Stage Present Operation	Ordinary Spring Stage Present Operation
Winnibigoshish	12.0 - 8.0	10.5 - 10.0	8.0
Leech	3.0 - 0.5	2.2 - 1.8	0.5
Pokegama	10.0 - 6.0	9.25 - 8.75	6.0
Sandy	11.0 - 7.0	9.25 - 8.75	7.0
Pine	14.0 - 11.0	13.25 - 12.75	11.0
Gull	7.0 - 5.0	6.25 - 6.0	5.0

XIX

The need has occurred in the past and will continue to occur in the future for retention of water in and release of water from the reservoirs for navigation, flood control, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation, and other purposes and for emergency conditions in the Mississippi River headwaters and downstream. It is necessary that sufficient water be stored in the reservoir to meet these needs when they arise.

XX

The need has occurred in the past and will continue in the future for the maintenance of desirable levels in the reservoirs for wildlife resources, wild rice production, recreational activities, resort operation, and game and fish production.

Upon the foregoing findings of fact, the Commissioner of Conservation makes the following

CONCLUSIONS

I

That the plan formulated by the Commissioner of Conservation for the operation of the dams controlling each of the above named reservoirs, as presented in the following Order, complies with the requirements of Minnesota Statutes 1961, Sections 110.49 and 110.50.

Upon the foregoing findings of fact and conclusions, the Commissioner of Conservation makes the following

ORDER

I

The following plan for the operation of the dams controlling the reservoirs formed by the headwater lakes of the Mississippi River, including Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine River (the Whitefish Chain), Sandy Lake, and Gull Lake is hereby determined upon as the plan to be put into effect pursuant to Minnesota Statutes, 1961, Section 110.51.

1. The minimum stage basically recognized for each reservoir, and the maximum stage for each reservoir that shall not be exceeded insofar as practicable in providing reasonable fluctuations for the production of wild rice, for the production and maintenance of wildlife resources and for the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes; and the most desirable height for each reservoir during the recreational season, all shall be as shown in Table A.

TABLE A

	Most Desirable Height Feet	Minimum Stage Basically Recognized Feet	Maximum Stage Insofar as Practicable Feet
Winnibigoshish	10.25	6.0	12.0
Leech	2.0	0.0	3.5
Pokegama	9.00	6.0	12.0
Sandy	9.0	7.0	11.0
Pine	13.0	9.0	14.0
Gull	6.1	5.0	7.0

2. When a reservoir stage is at the minimum stage basically recognized for that reservoir, the maximum discharge shall not exceed the value shown in Table B. Further limitations on discharge at stages lower than the minimum basically recognized are provided in this order in Table D.

TABLE B

	Minimum Stage Basically Recognized Feet	Maximum Discharge Cubic Feet Per Second
Winnibigoshish	6.0	900
Leech	0.0	150
Pokegama	See special provision below	
Sandy	7.0	200
Pine	9.0	100
Gull	5.0	100

3. When a reservoir stage is above the maximum stage that shall not be exceeded insofar as practicable, the discharge shall not exceed the value tabulated in Table C.

TABLE C

	Maximum Stage Insofar as Practicable Feet	Maximum Discharge Cubic Feet Per Second
Winnibigoshish	12.0	4,500
Leech	3.5	1,700
Pokegama	12.0	5,500
Sandy	11.0	3,800
Pine	14.0	2,500
Gull	7.0	1,400

4. The following special provision shall apply to Pokegama Reservoir:

a. The minimum stage basically recognized shall be 6.0 feet. When the stage is below 6.0, the discharge shall not exceed 200 cubic feet per second except when water is being released from either Winnibigoshish Reservoir or Leech Reservoir or both for navigation, flood control, industry, municipal water supply and sewage disposal, power generation and other purposes. Furthermore, if the stage of Pokegama Reservoir is below 6.0 or any other desired stage, the discharge shall be regulated ordinarily so that it is not greater than the sum of the discharges from Winnibigoshish Reservoir and Leech Reservoir, when the discharge is not over 100 cubic feet per second from each. When discharges from Winnibigoshish Reservoir or Leech Reservoir or both are increased to provide greater flows for navigation, flood control,

industry, municipal water supply and sewage disposal, power generation and other purposes, the discharge from Pokegama Reservoir may be increased at the same time or shortly thereafter to a flow not greater than the sum of the discharges from Winnibigoshish Reservoir and Leech Reservoir, if Pokegama Reservoir is at a stage below 6.0 or below a desired stage higher than 6.0. When Pokegama Reservoir is at a stage higher than the stage then desired, the discharge need not be limited by the discharges from Winnibigoshish and Leech Reservoir.

b. When Pokegama Reservoir is not being regulated to release water for industry, municipal water supply and sewage disposal, power generation and other purposes under authorization by the Commissioner of Conservation, in accordance with the general and special provisions above, and is not being regulated by the Corps of Engineers for navigation or flood control, the discharges shall be regulated to provide the most desirable height for this reservoir or slightly higher or lower stages most desirable for fish, game, wildlife, wild rice and recreational purposes, as recommended by the Division of Game and Fish, Minnesota Department of Conservation, through the Division of Waters.

5. Winnibigoshish, Leech, Sandy, Pine and Gull Reservoirs shall be operated at all times for the primary purposes of navigation and flood control and stages and discharges shall be regulated accordingly, but when storage or release of water is not required for these purposes, the limitations in Tables A, B, C and D relating to stage and discharge for these reservoirs shall apply and regulation shall be such that the water will be at or near the most desirable height during the desired period insofar as practicable, except when discharges must be made to meet the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes.

6. In operating Winnibigoshish, Leech, Sandy, Pine and Gull Reservoirs in accordance with the above plan the discharges shall be regulated ordinarily so that the discharge for each reservoir is the value shown in Table D when the reservoir stages are in the tabulated stage range.

TABLE D

Reservoir	Stage Range At Or Above	Below	Discharge Cubic Feet Per Second
Winnibigoshish		6.0	50
	6.0	8.0 or 10.25*	100
Leech		0.0	50
	0.0	0.5 or 2.0*	1[illegible]
Sandy		7.0	10
	7.0	9.0**	20

Pine		9.0	15
	9.0	13.00**	30
Gull		5.0	10
	5.0	6.1**	20

*The higher or lower of these two stages will govern, depending on which is the desired stage at the time under consideration.
**or other desired stage.

7. When greater flows than are tabulated in Table D are required from one or more reservoirs for industry, municipal water supply and sewage disposal, power generation and other purposes, the discharge may be increased if authorized by the Commissioner, but shall not exceed the value shown in Table E opposite the then prevailing stage for each reservoir from which water is to be released. When there is a great increase in discharge for any stage shown in the table for any reservoir over the discharge for the next lower tabulated stage, the release of water for these purposes shall not be at a rate greater than a discharge limit calculated by proportion for the prevailing stage, between the tabulated discharge at the upper limit of the range in which the prevailing stage occurs and the tabulated discharge at the lower limit of that range. Increased discharges from Pokegama Reservoir for these purposes will be governed by the special provisions above for that reservoir.

TABLE E

WINNIBIGOSHISH RESERVOIR		LEECH RESERVOIR	
Gage Datum Stage, Feet	Discharge Cu. Ft. per Sec.	Gage Datum Stage, Feet	Discharge Cu. Ft. per Sec.
1.0	50	-1.0	50
2.0	100	-0.5	100
3.0	300	0.0	150
4.0	500	0.5	200
5.0	700	1.0	400
6.0	900	1.5	600
7.0	1100	2.0*	1100
8.0	2100	2.5	1400
9.0	3100	3.0	1500
10.0	4500	3.5	1600
10.25*	4500	4.0	1700
over 10.25	4500	over 4.0	1700

*Most desirable stage for recreational purposes.

SANDY RESERVOIR

Gage Datum Stage, Feet	Discharge Cu. Ft. per Sec.
0.0	10
1.0	20
2.0	40
3.0	60
4.0	80
5.0	100
6.0	150
7.0	200
8.0	400
9.0*	1400
10.0	2400
11.0	3800
over11.0	3800

PINE RESERVOIR

Gage Datum Stage, Feet	Discharge Cu. Ft. per Sec.
1.0	15
2.0	30
3.0	40
4.0	50
5.0	60
6.0	70
7.0	80
8.0	90
9.0	100
10.0	200
11.0	300
12.0	400
13.0*	500
14.0	2500
over 14.0	2500

*Most desirable stage for recreational purposes.

GULL RESERVOIR

Gage Datum Stage, Feet	Discharge Cu. Ft. per Sec.
3.0	10
3.5	20
4.0	40
4.5	60
5.0	100
5.5	200
6.0	400
6.1*	
6.5	600
7.0	1000
7.5	1400

*Most desirable stage for recreational purposes.

8. Unless discharge of water is needed for flood control or navigation, discharges from any reservoir shall not exceed the values in Table D, if the prevailing reservoir stage is within the range shown in Table D, except upon written application to the Commissioner of Conservation by a representative of a public corporation, of a political or governmental subdivision of the State of Minnesota or by an industry or power producer or by an individual. The application shall be considered only if the public corporation, political subdivision, industry, power producer, or individual owns or leases land riparian to the Mississippi within the State of Minnesota or riparian to a reservoir outlet stream, or is located adjacent to the Mississippi River or to a reservoir outlet stream within the State.

9. Discharges from Leech Reservoir in excess of the values in Table D, if the prevailing reservoir stage is within the range shown in Table D, shall be made for industry, municipal water supply and sewage disposal, power generation and other purposes only when discharge from Winnibigoshish Reservoir is limited because of its stage to less than the total discharge authorized by the Commissioner for these purposes, unless the use for which the release is authorized will be made along the Leech Lake River.

10. Discharges from Sandy, Pine and Gull Reservoirs in excess of the values in Table D, if the prevailing reservoir stage is within the range shown in Table D, shall be made for industry, municipal water supply and sewage disposal, power generation and other purposes only when discharged from Winnibigoshish and Leech Reservoirs is limited because of their stages to less than the total discharge authorized by the Commissioner for these purposes, unless the use for which the release is authorized is along the Sandy River, the Pine River, or the Gull River.

11. An application for release of water for industry, municipal water supply and sewage disposal, power generation and other purposes may be granted or denied by the Commissioner, or the release of water in response to the application, but in lesser quantity than requested, may be authorized. His action is responce to such an application shall depend upon the urgency of the need for water. The needs and rights of other water users and property owners along the river, and the current situation of recreational interests, and game and fish and wild rice needs, and due consideration shall be given to the minimum stages basically recognized as set forth in Table A. The quantity of water to be released from each reservoir shall be coordinated with quantities to be released from other reservoirs to make up the total authorized release of water.

12. Except when the release of water for industry, municipal water supply and sewage disposal, power generation and other purposes is authorized by the Commissioner of Conservation or the reservoirs are being regulated by the Corps of Engineers for navigation or flood control, the discharges shall be regulated to provide the most desirable height for each reservoir or slightly higher or lower stages most desirable for fish, game, wildlife, wild rice and recreational purposes, as recommended by the Division of Game and Fish, Minnesota Department of Conservation, through the Division of Waters. When the stage in any reservoir is above such recommended height and regulation is directed toward providing the recommended height, the discharge from that reservoir shall not exceed the tabulated discharge shown in Table E for the stage then prevailing in that reservoir.

13. The Division of Game and Fish recommendations for operating each reservoir will be kept on file in the offices of the Department of Conservation. These recommendations will be subject to change from time to time in accordance with conditions in and near the reservoirs and outlet streams.

Dated at St. Paul, Minnesota, this 19th day of April, 1963.

/s/ Clarence Prout
Clarence Prout
Commissioner of Conservation

SESSION LAWS OF MINNESOTA FOR 196[illegible]

CHAPTER [illegible]--S.F. No. [illegible]
(Coded)

An Act relating to the regulation and control of water elevations and for determining authorized discharges from the Headwater lakes of the Mississippi River, including Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine River (the Whitefish Chain), Sandy Lake, and Gull Lake.

Be it enacted by the Legislature of the State of Minnesota:

Section 1. (110.47) Headwater lakes of Mississippi, reason for control. It is the considered judgment of the Legislature of the State of Minnesota that the regulation, control, and utilization of waters in the Headwater lakes in the Mississippi River, including Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine River (the Whitefish Chain), Sandy Lake, and Gull Lake are of tremendous economic importance and value to the State of Minnesota. It is further the considered judgment of the Legislature of Minnesota that the utility of these lakes in aid of navigation has been very greatly diminished since the time of the establishment of the reservoirs, and that the economic values in utilization of these waters for State purposes has increased tremendously. These factors require the assertion on the part of the State of Minnesota of its rights to utilization and control of these water areas.

Section 2. (110.48) Joint Federal-State control. The Commissioner of Conservation is authorized and directed to enter into cooperative agreements with the United States of America acting through the Department of the Army for the joint control and regulation of these reservoirs within the principles hereinafter prescribed so as to effectuate control of the water elevations and the water discharges from these lakes in the interests of the State of Minnesota, subject only to any paramount need of waters from these sources in aid of substantial navigation requirements, and subject further to any substantial requirement of providing necessary flood control storage capacity as determined by the Corps of Army Engineers.

Section 3. (110.49) Plan for dam operation. The Commissioner of Conservation is hereby authorized and directed to formulate a plan for the operation of the dams controlling each of the reservoirs hereinabove named which will:

(a) Seek to establish the water elevation on each of the lakes at the most desirable height, and to stabilize the stages at that point, insofar as practicable, during the recreational season in Minnesota;

(b) Give due consideration to providing for any reasonable fluctuations when desirable for the production of wild rice in the wild rice producing areas of these lakes;

(h) Take into account the elevations most desirable for the production and maintenance of wildlife resources;

(i) Give due consideration to needs of water for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation, and other purposes in the Mississippi River headwaters and downstream;

(j) Establish stages at which the water shall be maintained so far as practicable, but basically recognizing the following minimum stages in reference to present zeros on the respective Government gauges:

Leech Lake	0.0
Winnibigoshish Lake	6.0
Pokegama Lake	6.0
Sandy Lake	7.0
Pine River	9.0
Gull Lake	5.0

(k) Prescribe maximum discharges at any time the elevations fall below such stages;

(l) Prescribe maximum elevations and amounts of discharge from each lake so as best to stabilize and effectuate the desired stages. Insofar as practicable, the following maximum lake stages shall not be exceeded:

Leech Lake	3.5
Winnibigoshish Lake	12.0
Pokegama Lake	12.0
Sandy Lake	11.0
Pine River	14.0
Gull Lake	7.0

<u>Section 4</u>. (110.50) <u>Potentials comprehended by plan</u>. The plan devised by the Commissioner shall comprehend the following potentials:

(a) The necessity for changing discharges to meet any emergencies resulting from unexpected or abnormal inflows;

(b) The possibility of overriding requirements of the Federal Government for substantial discharges to meet reasonable and substantial navigation requirements;

(c) The overriding authority and needs as prescribed by the Army Engineers in discharging their functions of requiring additional storage capacity for flood control purposes.

<u>Section 5</u>. (110.51) <u>Notice of plan; hearing</u>. Before the plan of operation for any Headwater lake is put into effect the Commissioner shall publish a notice of hearing upon said plan for two weeks in a

newspaper in each County in which the water areas to be affected lie. The hearing shall be conducted by the Commissioner or his duly appointed referee. All interested parties shall have an opportunity to be heard, shall testify under oath, and shall be subject to cross examination by any adverse parties, and by the Attorney General, or his representative, who shall represent the Commissioner at said hearing. The hearing will not be governed by legal rules of evidence, but the findings of fact and orders, to be made and formulated by the Commissioner, shall be predicted only upon relevant material, and competent evidence. The findings of fact and orders incorporating the plan determined upon by the Commissioner shall be published for two weeks in the same manner as the notice of hearing was published.

Section 6. (110.52) Appeal. Any riparian landowner or water user aggrieved by such findings shall have the right to appeal within 30 days of the completion of publication to the district court of any County in which the regulated water lies, which appeal shall be determined by the court on the record made before the Commissioner of Conservation. Issues on any such appeal shall be the legal rights of the parties and the further question as to whether the findings of the Commissioner are reasonably supported by the evidence adduced at the hearing.

Section 7. (110.53) Modification. It is recognized that experience may require changes in the elevations sought to be maintained on each of the Headwater lakes. Consequently, once a plan has been put into effect, the Commissioner is authorized to modify the stages sought to be maintained by modifying his plan with respect to any of the lakes involved to the extent of one foot in elevation according to the zeros of the present Government gauges without the necessity of further or additional hearings; provided that in no event shall any departure from the elevation target be made so as to reduce any proposed stages below the minimums prescribed by Section 3 (d) during the recreational season. Any modification of the plan established subsequent to the hearings herein provided which departs by more than one foot in elevation shall be placed into effect only upon further hearing proceeding upon the same formalities as the hearing hereinabove prescribed.

Approved April 20, 1961.

PLAN OF OPERATION FOR WINNIBIGOSHISH RESERVOIR
IN ACCORDANCE WITH LAWS OF 1961, CHAPTER 459

STATE OF MINNESOTA

The most desirable height for this reservoir during the recreational season shall be a gauge height of 10.25 feet. In providing reasonable fluctuations for the production of wild rice, for the production and maintenance of wildlife resources, and for the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes, the minimum stage basically recognized shall be 6.0 and, insofar as practicable and maximum stage 12.0 shall not be exceeded.

When the stage is below 6.0, the maximum discharge shall not exceed the tabulated value for the prevailing stage. Even through the stage is above 12.0, the maximum discharge shall not exceed 4,500 cubic feet per second.

The reservoir shall be operated at all times for its primary purposes of navigation and flood control and stages and discharges shall be regulated accordingly, but when storage or release of water is not required for these purposes, the above limitations shall apply and regulation shall be such that the water will be at or near the most desirable height during the desired period, insofar as practicable, except when discharges must be made to meet the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes.

In operating the reservoir in accordance with the above plan, the discharge shall be regulated ordinarily so that discharge is 50 cubic feet per second when the reservoir stage is below 6.0 and so that the discharge is 100 cubic feet per second when the reservoir is above 6.0 but below 8.0 or 10.25 at times when it is desired that the reservoir be at these stages. When greater flows are required for industry, municipal water supply and sewage disposal, power generation and other purposes, the discharge may be increased if authorized by the Commissioner but shall not exceed the tabulated value opposite the prevailing reservoir stage.

Gauge Datum Stage, Feet	Discharge, Cubic Feet Per Second	Gauge Datum Stage, Feet	Discharge, Cubic Feet Per Second
1.0	50	9.0	3100
2.0	100	10.0	4500
3.0	300	10.25*	
4.0	500	11.	4500
5.0	700	12.	4500
6.0	900	13.	4500
7.0	1100	14.	4500
8.0	2100		

*Most desirable stage for recreational purposes.

Unless discharge of water is needed for flood control or navigation, discharges in excess of 50 c.f.s. when the reservoir stage is below 6.0 or in excess of 100 c.f.s. when the reservoir is below a desired stage higher than 6.0 shall be made only upon written application to the Commissioner of Conservation by a representative of a public corporation, of a political or Governmental subdivision of the State of Minnesota, or by an industry or power producer, and shall be considered only if the public corporation, political subdivision, industry, or power producer owns or leases land riparian to the Mississippi River within the State of Minnesota, or is located adjacent to the river within the State.

An application for release of water for these purposes may be granted or denied by the Commissioner or the release of water in response to the application but in lesser quantity than requested may be authorized. His action in response to such application shall depend upon the urgency of the need for water, the needs and rights of other water users and property owners along the river, and the current situation of recreational interests, and game and fish and wild rice needs. The quantity of water to be released from this reservoir shall coordinate with quantities to be released from other headwaters reservoirs to make up the total authorized release of water.

Except when the release of water for industry, municipal water supply and sewage disposal, power generation and other purposes is authorized by the Commissioner of Conservation or the reservoir is being regulated by the Corps of Engineers for navigation or flood control, the discharges shall be regulated to provide the most desirable height for this reservoir or slightly higher or lower stages most desirable for fish, game, wildlife, wild rice, and recreational purposes, as recommended by the Division of Game and Fish, Minnesota Department of Conservation, through the Division of Waters. When stages are above these recommended stages, and regulation is directed toward providing the recommended stage, discharges shall not exceed the tabulated discharge for the then-prevailing stage.

<u>Current Division of Game and Fish Recommendations for Operating Winnibigoshish Reservoir</u>. When conditions will permit, any increase or decrease in discharge from Winnibigoshish Reservoir should be made so that the rate of outflow does not change more than 50 cubic feet per second each day, when the total change is to be less than 300 c.f.s., or so that the rate of outflow does not change more than 100 cubic feet per second each day when the total change is to be more than 300 c.f.s. A change at a rate of 100 c.f.s. every other day will be acceptable, as a substitute for a change of 50 c.f.s. each day.

Late winter or early spring minimum stages should be determined each year as those levels from which summer levels can be attained by June 1 with anticipated rainfall and runoff. The minimum spring stage should be no less than 8.0, and preferably 8.5. Winter drawdown of the reservoir should not begin prior to September 15.

At no time should there be a complete shutdown of Winnibigoshish Dam. It is necessary that there be some flow in the Mississippi River below the dam for maintenance of aquatic habitat. The minimum winter discharge should be 50 c.f.s.

During the summer months, reservoir discharges should be regulated so far as practicable so that the reservoir stage remains between 9.0 and 10.0.

PLAN OF OPERATION FOR LEECH LAKE RESERVOIR IN ACCORDANCE WITH LAWS OF 1961, CHAPTER 459

STATE OF MINNESOTA

The most desirable height for this reservoir during the recreational season shall be a gauge height of 2.0 feet. In providing reasonable fluctuations for the production of wild rice, for the production and maintenance of wildlife resources and for the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes, the minimum stage basically recognized shall be 0.0 and, insofar as practicable, the maximum stage 3.5 shall not be exceeded.

When the stage is below 0.0, the maximum discharge shall not exceed the tabulated value for the prevailing stage. Even though the stage is above 3.5, the maximum discharge shall not exceed 1,700 cubic feet per second.

The reservoir shall be operated at all times for its primary purposes of navigation and flood control and stages and discharges shall be regulated accordingly, but when storage or release of water is not required for these purposes, the above limitations shall apply and regulation shall be such that the water will be at or near the most desirable height during the desired period, insofar as practicable, except when discharges must be made to meet the water needs for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation and other purposes.

In operating the reservoir in accordance with the above plan, the discharge shall be regulated ordinarily so that discharge is 50 cubic feet per second when the reservoir stage is below 0.0 and so that discharge is 100 cubic feet per second when the reservoir is above 0.0 but below 0.5 or 2.0 at times when it is desired that the reservoir be at these stages. When greater flows are needed for industry, municipal water supply and sewage disposal, power generation and other purposes, the discharge may be increased if authorized by the Commissioner but shall not exceed the tabulated value opposite the prevailing reservoir stage:

Gauge Datum Stage, Feet	Discharge, Cubic Feet Per Second	Gauge Datum Stage, Feet	Discharge, Cubic Feet Per Second
-1.0	50	2.5	1400
-0.5	100	3.0	1500
0.0	150	3.5	1600
0.5	200	4.0	1700
1.0	400	4.5	1700
1.5	600	5.0	1700
*2.0	1100	5.5	1700

*Most desirable stage for recreational purposes.

Unless discharge of water is needed for flood control or navigation, discharges in excess of 50 c.f.s. when the reservoir stage is below 0.0 or in excess of 100 c.f.s. when the reservoir is below a desired stage higher than 0.0 shall be made only upon written application to the Commissioner of Conservation by a representative of a public corporation, of a political or Governmental subdivision of the State of Minnesota, or by an industry or power producer, and shall be considered only if the public corporation, political subdivision, industry, or power producer owns or leases land riparian to the Leech Lake River or the Mississippi River within the State of Minnesota, or is located adjacent to these rivers within the State.

Discharges in excess of 50 c.f.s. with the reservoir stage below 0.0 and in excess of 100 c.f.s. with the reservoir stage above 0.0 but below 0.5 or 2.0 for industry, municipal water supply and sewage disposal, power generation and other purposes shall be made from Leech Lake Reservoir only when discharge from Winnibigoshish Reservoir is limited because of its stage to less than the total discharge authorized for these purposes, unless the use for which the release is authorized will be made along the Leech Lake River.

An application for release of water for these purposes may be granted or denied by the Commissioner or the release of water in response to the application but in lesser quantity than requested may be authorized. His action in response to such an application shall depend upon the urgency of the need for water, the needs and rights of other water users and property owners along the river, and the current situation of recreational interests, and game and fish and wild rice needs. The quantity of water to be released from this reservoir shall be coordinated with quantities to be released from other headwaters reservoirs to make up the total authorized release of water.

Except when the release of water for industry, municipal water supply and sewage disposal, power generation and other purposes is authorized by the Commissioner of Conservation or the reservoir is being regulated by the Corps of Engineers for navigation or flood control, the discharges shall be regulated to provide the most desirable height for this reservoir or slightly higher or lower stages most desirable for fish, game, wildlife, wild rice, and recreational purposes, as recommended by the Division of Game and Fish, Minnesota Department of Conservation, through the Division of Waters. When stages are above these recommended stages and regulation is directed toward providing the recommended stage, discharges shall not exceed the tabulated discharge for the then-prevailing stage.

Current Division of Game and Fish Recommendations for Operating Leech Lake Reservoir. Whenever conditions will permit, any increase or decrease in discharge from Leech Lake Reservoir should be made so that the rate of outflow does not change more than 50 cubic feet per second each day, or 100 c.f.s. every other day, when the total change is to be less than 300 c.f.s., or so that the rate of outflow does not change more than 100 cubic feet per second each day, when the total change is to be more than 300 c.f.s.

Late winter or early spring minimum stages should be determined each year as those levels from which summer levels can be attained by June 1 with anticipated rainfall and runoff. The minimum spring stage should be 0.5. Winter drawdown of the reservoir should not begin prior to September 15.

At no time should there be a complete shutdown of Leech Lake Dam. It is necessary that there be some flow in the Leech Lake River below the dam for maintenance of aquatic habitat. The minimum winter discharge should be 50 c.f.s.

During the summer months, reservoir discharges should be regulated so far as practicable so that the reservoir stage remains between 1.8 and 2.2.

GOVERNOR'S 1975 REQUEST FOR LOWER LEVEL FOR LAKE WINNIBIGOSHISH

The normal summer operating level for Lake Winnibigoshish was lowered 1 foot from the 10.0- to 10.5-foot stage (1298.94 to 1299.44 elevation) to the 9.0- to 9.5-foot stage (1297.94 to 1298.44 elevation) in 1976. This lower level will be maintained for a trial period of 5 years as a result of a 19 March 1975 letter request by the Governor of Minnesota. The normal summer level may be continued at this lower level after the 5-year trial period if it appears the public interest is best served by this revised operation. The 19 April 1963 State of Minnesota Commissioner of Conservation order would be appropriately modified at that time.

The Governor's request for lower operating levels originated because of local concern for shoreline erosion control. A detailed 1965 report by the U.S. Forest Service on the erosion problem on Lake Winnibigoshish supported the need for lower levels to control shoreline erosion. A copy of the Governor's request letter follows.

[illegible] R. ANDERSON
GOVERNOR

STATE OF MINNESOTA

OFFICE OF THE GOVERNOR

ST. PAUL 55155

March 19, 1975

Colonel Max Noah,
District Engineer
U. S. Army Corps of Engineers
St. Paul, Minnesota

Dear Colonel Noah:

As a result of recent meetings between members of the Minnesota Legislature and personnel of the Minnesota Department of Natural Resources, the Metropolitan Council and the U. S. Corps of Engineers, I have been informed that a number of the shoreland residents around Winnibigoshish Reservoir are greatly concerned about bank erosion. As a measure to reduce such erosion, the local residents have requested a change in the normal summer operating levels of the reservoir. Information available to the Department of Natural Resources indicates that the summer level preferred by the shoreland [illegible] is within the range of 9.0 to 9.5 feet on the official gage for the Winnibigoshish Reservoir.

The Department of Natural Resources has advised [illegible] the proposed change in levels, which represents a one-foot [illegible] in the present normal summer operating levels, would not be [illegible]mental to natural resources management plans in the [illegible]. [illegible] also advised that there is some concern by downstream interests, particularly in the Twin City area, over possible losses in available storage for downstream flow augmentation for certain essential uses, particularly for low-flow augmentation for Twin Cities waste discharge assimilation in the Mississippi River.

In view of the situation, I request the U. S. Corps of Engineers to consider the residents' proposal to adopt, for Winnibigoshish Reservoir, a normal summer operating range of levels of 9.0 to 9.5 feet on the U. S. Corps of Engineers gage, on an experimental basis, subject to alteration by the Corps if flow conditions detrimental to downstream [illegible]

Page Two
Colonel Max Noah
March 19, 1975

interests occur as a result. I would also appreciate the assistance of the Corps in informing me of the capability of the Corps to complete the Corps study evaluating alternative plans of operation of the Mississippi Headwaters Reservoirs in Minnesota. This study was requested by the State of Minnesota to Congress for adequate evaluation for the best operation of the Headwaters Reservoirs.

This request is not inconsistent with the provisions of Minnesota Statutes, Sections 110.47 through 110.53 or with the order of the Commissioner of Conservation of April 19, 1963 which implemented that statutory provision. It is intended that the Commissioner's order of April 19, 1963 would be modified only to the extent necessary to provide for the charge in summer levels of Winnibigoshish Reservoir an experimental basis.

Thank you for your cooperation on this matter.

Sincerely,

Wendell R. Anderson

Wendell R. Anderson

WRA:skf

cc: Representative Glen Sherwood
Senator Gerald Willet
Robert L. Herbst, Commissioner of the Department of Natural Resources
Frank Lamm, Metropolitan Council
Eugene R. Gere, Director, Division of Water, Soils and Minerals, DNR

The 5-year trial period requested by the Governor ended in 1980, and the results indicated that the 9.0- to 9.5-foot summer operating level was acceptable to most interests. Complaints to the St. Paul District concerning water levels at Lake Winnibigoshish were reduced dramatically. The State Archeologist reported that erosion of shoreline archeological sites was reduced.

Then, early in 1980, the Minnesota Department of Natural Resources' (DNR) Fisheries Section requested a modification in the regulation of springtime lake levels to optimize the success of walleye spawning and DNR spawn-taking operations on Little Cutfoot Sioux Lake. The DNR subsequently met with the Corps, and it was decided to extend the previous 5-year trial maximum summer operating level of 9.5 for another 5 years (1981-1985). The proposed operation to optimize walleye spawning and spawn taking closely matched the operation desired for shoreline erosion control. The operation for walleyes involves the following conditions.

a. Draw the lake down from September to April. The Corps would coordinate with the Minnesota DNR to attempt to ensure that an adequate water level (8.5 feet) is available at the beginning of the walleye spawning season (about 25 April).

b. Coordination with the Minnesota DNR during spawning season (about 2 weeks) to attempt to control Lake Winnibigoshish levels in order to induce a walleye spawning run into Little Cutfoot Sioux Lake.

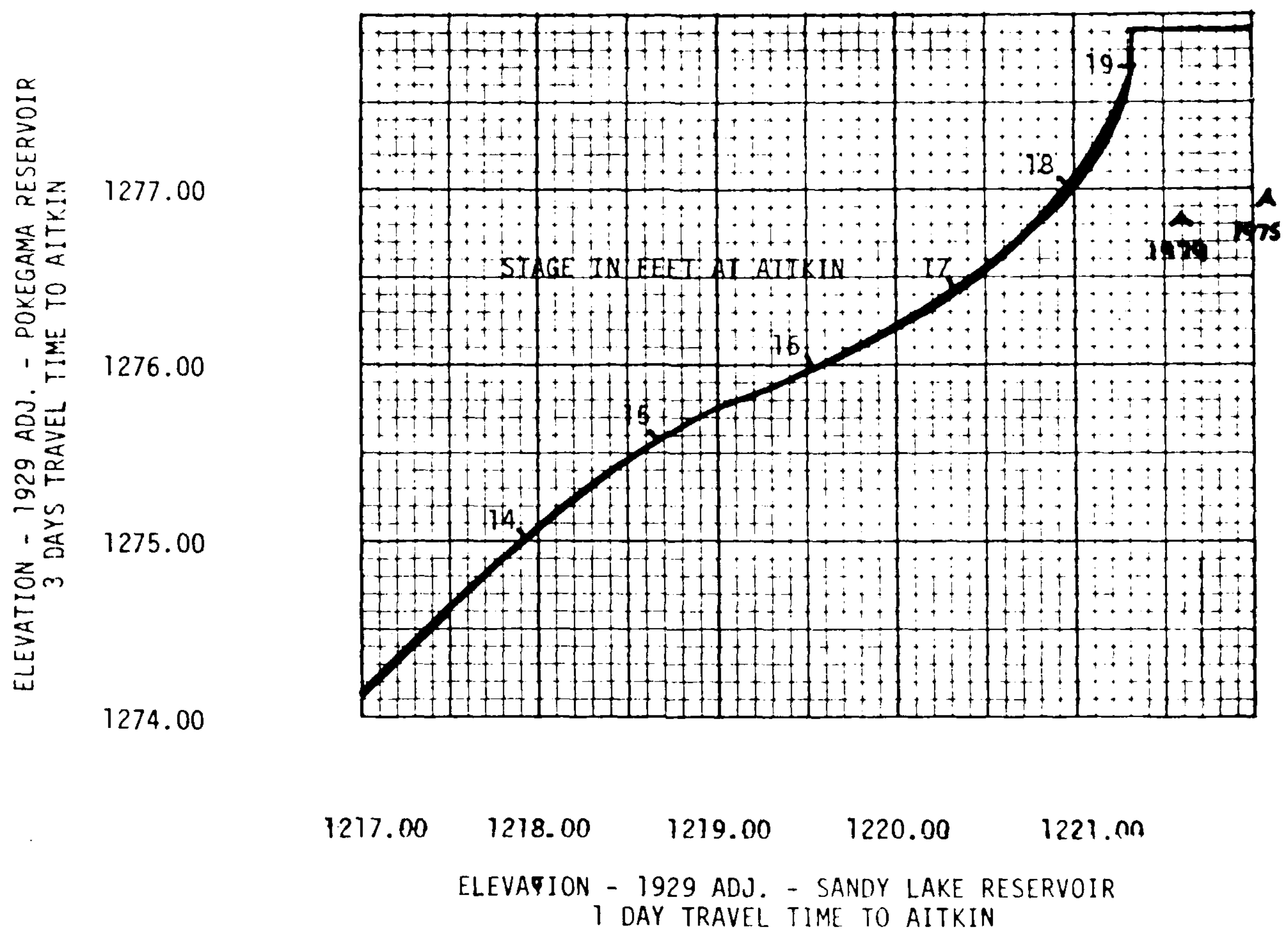
c. Maintaining summer levels at 9.0 to 9.5 feet.

The above plan of operation consists of target levels which may or may not be met in any given year, depending on climatic conditions. For example, under drought conditions, the lake would not be drawn to normal levels and runoff might not be sufficient to fill the lake to normal summer levels. In heavy precipitation years, normal summer levels may be exceeded.

An environmental assessment of the modification to optimize walleye production was prepared in March 1981. The Environmental Protection Agency approved the assessment on 1 April 1981, and the District Engineer's Finding of No Significant Impact was issued on 24 July 1981.

1977 TENTATIVE GUIDE CURVES FOR SPRING AND SUMMER FLOODS (POKEGAMA-SANDY-AITKIN)

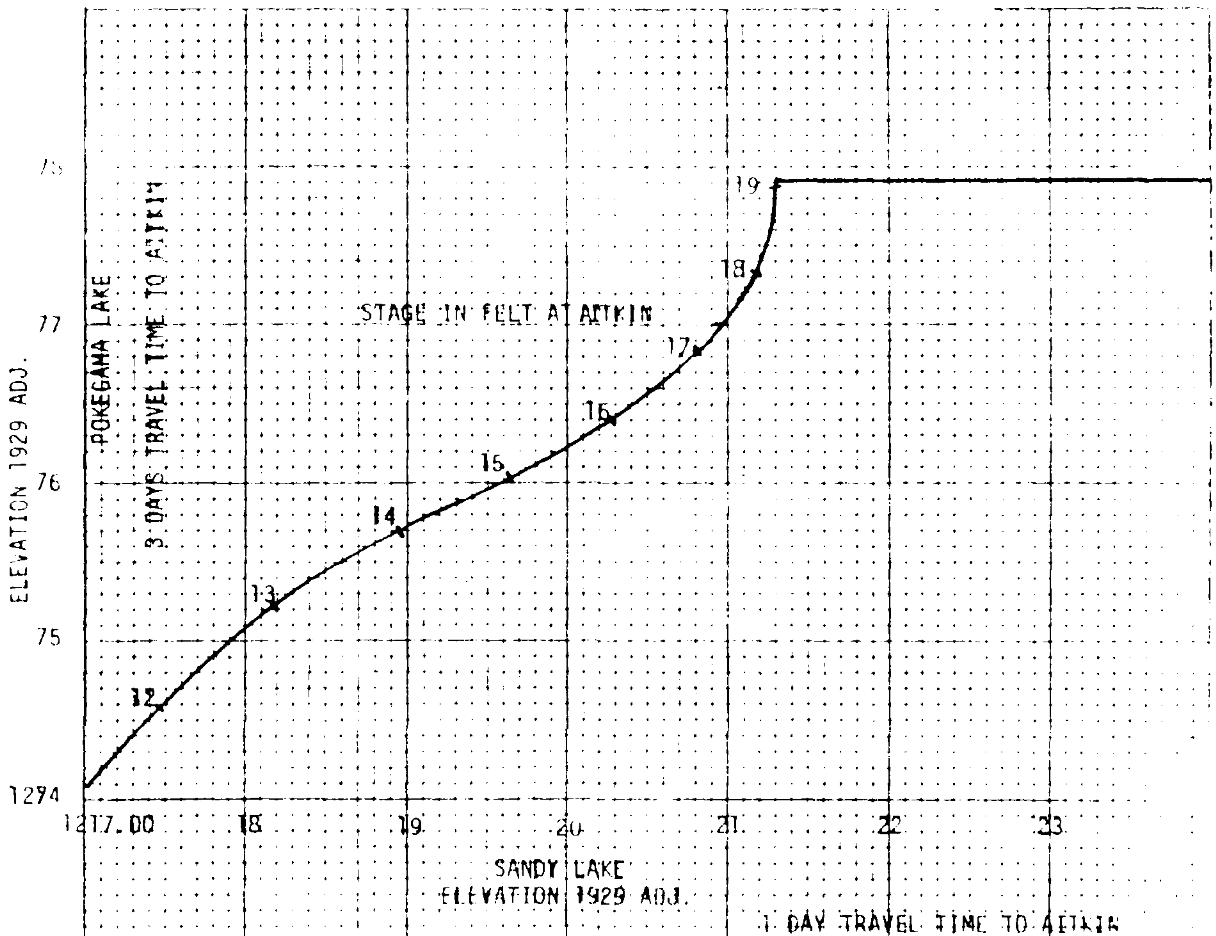
The tentative guide curves developed in 1956 have not been revised to date. However, the Aitkin gage zero was lowered by 3 feet in 1967 to eliminate negative stages and, since 1973, water levels for the six headwaters lakes, previously reported in stage, are reported in elevation above mean sea level. The following tentative curves dated 1977 were redrawn to reflect these technical changes. In actual content, the 1977 curves are identical to the earlier 1956 curves. The 1975 and 1976 observed peaks are also shown on the appropriate curve for comparison.



NOTE:
Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

Aitkin Gage Zero = 1182.41
Pokegama Gage Zero = 1264.42
Sandy Gage Zero = 1207.31

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAMS AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL
TENTATIVE GUIDE CURVE
SPRING FLOODS (MAR.-15 MAY)



NOTE

Curve shows relation between maximum reservoir stages and corresponding peak flood stage on the Mississippi River at Aitkin which, under operating procedures now in effect, will result (on the average) in the minimum total flood damages to affected interests in the three principal damage areas.

[illegible] 1132.[illegible]
[illegible] 1261.[illegible]
[illegible]

NAVIGATION AND FLOOD CONTROL
MISSISSIPPI RIVER, MINNESOTA
HEADWATERS DAM AND RESERVOIRS
MASTER
RESERVOIR REGULATION MANUAL
TENTATIVE GUIDE CURVE
SUMMER FLOODS ([illegible] May-Sept)

FEB 28 1977

The following important facts about the Pokegama-Sandy-Aitkin guide curves should be emphasized:

1. The original (and thus current) guide curves were developed from an analysis of 14 actual flood events at Aitkin when elevations exceeded the 17-foot stage on the current gage. The analysis was therefore based on a certain amount of hindsight. Actual operations in any particular year can result in the use of more or less lake storage to effect stage reductions at Aitkin. Actual operations are also affected by the areal distribution and time-volume relationships of individual floods as well as the accuracy of flood forecasts.

2. Operating by the guide curves will not prevent flooding in the three affected areas. The curves reflect a peak flood stage relationship that helps minimize area damages as a result of lake operation capabilities.

3. The guide curves are not meant to be followed foot by foot as area stages rise in a particular flood event. The curves reflect maximum flood peak relationships which the operator normally forecasts for a particular event. To operate otherwise would unduly restrict the operator in the judicious use of lake storage at critical times during a flood. A good example is when the operator has the opportunity to "hedge" against [illegible] rainfall before, during, or just after peak flood events at Aitkin. By retaining some available storage in the two lakes, the operator [illegible] use of that storage in the event that rain in the area requires [illegible] storage to control or reduce the flood crest that would otherwise [illegible].

4. The maximum regulated elevations at Pokegama and Sandy Lakes are [illegible].9 (13.5-foot stage) and 1221.3 (14.0-foot stage), respectively. [illegible] these levels are exceeded, the outlet structures are no longer used [illegible] [illegible] flow releases. At that point the lakes are [illegible].

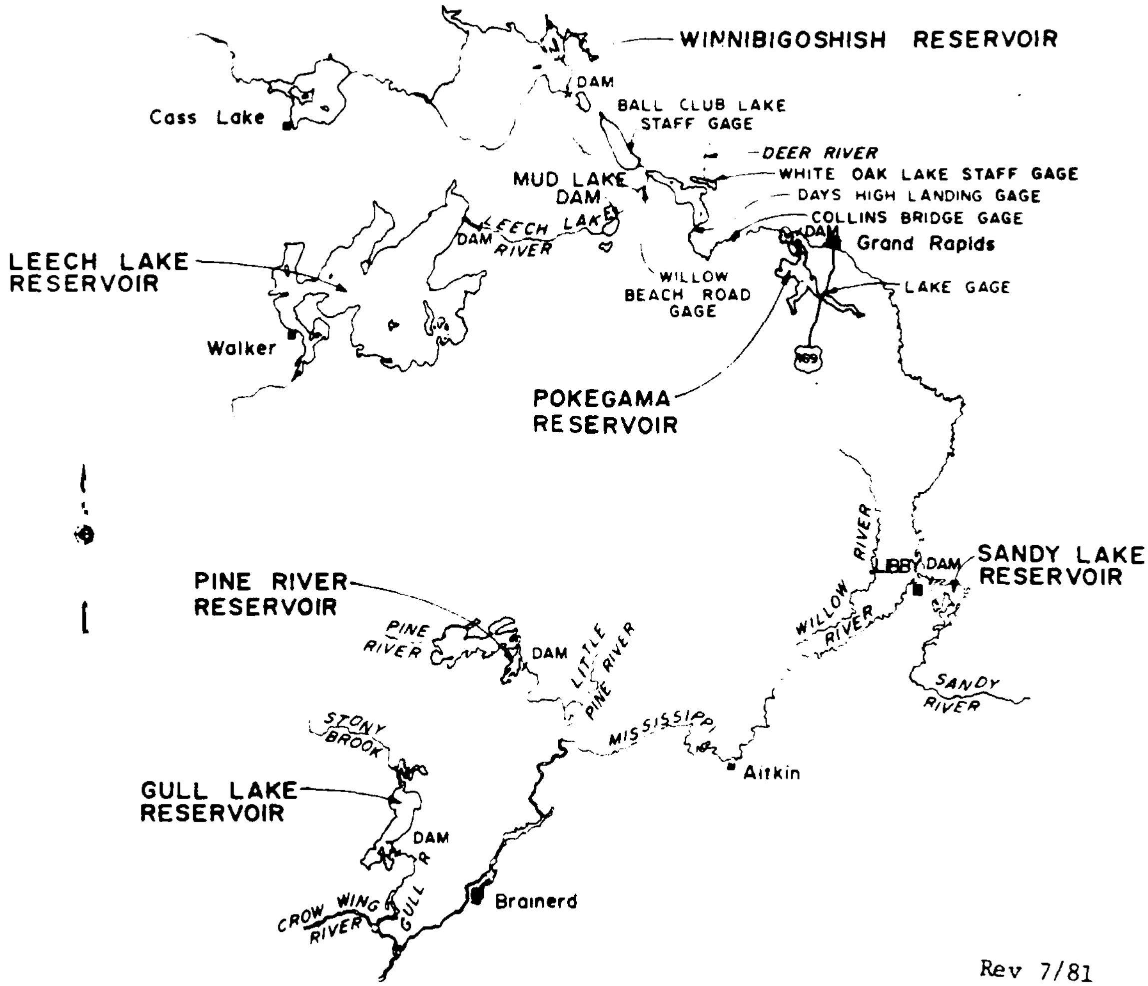
5. The drainage area between Aitkin and the upstream headwaters [illegible] considerable, and peak discharges can originate from that area alone. [illegible] example, [illegible] percent of the observed 19[illegible] Aitkin flood peak was attributable to the area downstream of the lakes.

CURRENT OPERATING PLAN AND RELEASE SCHEDULES

The current specific operating plans for the six Mississippi River Headwaters Lakes were developed over the years through regulations established by the War Department (now Department of the Army) and through demands and requirements of local and public interest groups expressed at a number of public meetings and hearings. Generally, operations of the four upper lakes (Winnibigoshish, Leech, Pokegama, and Sandy) are closely coordinated with each other and with the flood situation in the Aitkin area. Operations of Pine River and Gull Lakes are completely independent of each of the other lakes, except as required downstream flow releases for navigation and fish and wildlife purposes might dictate.

The following tabular summaries and narrative define the current operating plan and release schedules in detail. The summaries are appendixes to the April 1963 Master Reservoir Regulation Manual for the Mississippi River Headwaters Area. The summaries are updated to include trial operation levels on Lake Winnibigoshish and to include some corrections to storage capacities based on a review of lake elevation-storage curves. Trial operation [illegible] production (Leech Lake Conservation Plan- [illegible] the current operating limits and are not specifically [illegible] these summaries.

GENERAL OPERATING DATA - MISSISSIPPI RIVER HEADWATERS RESERVOIRS



LAKE ELEVATIONS IN FEET - 1929 ADJ.

RESERVOIR	WINNI-BIGOSHISH	LEECH	POKEGAMA	SANDY	PINE	GULL
NORMAL SPRING STAGE (DATE)	1296.94(3/1)	1293.20 (3/1)	1270.42(3/15)	1214.31(2/15)	1227.32(2/15)	1192.75(2/15)
DESIRABLE SUMMER RANGE	1298.94-1299.44	1294.50-1294.90	1273.17-1273.67	1216.06-1216.56	1229.07-1229.57	1193.75-1194.00
ORIGINAL OPERATING LIMITS	1288.94-1303.14	1292.20-1297.94	1268.92-1276.42	1207.91-1218.31	1217.62-1234.82	1188.75-1194.75
CAPACITY, ORIGINAL OPERATING LIMITS, AC-FT	967,900	743,300	120,800	78,700	178,900	70,800
PRESENT OPERATING LIMITS	1294.94-1303.14	1292.70-1297.94	1270.42-1276.42	1214.31-1218.31	1225.32-1231.32	1192.75-1194.75
PRESENT ORDINARY OPERATING LIMITS	1296.94-1300.94	1293.20-1295.70	1270.42-1274.42	1214.31-1218.31	1226.32-1230.32	1192.75-1194.75
DESIRABLE OPERATING LIMITS	1296.94-1299.44	1293.20-1295.70	1271.42-1274.42	1214.31-1218.31	1227.32-1230.32	1192.75-1194.75
CAPACITY, PRESENT OPERATING LIMITS, AC-FT	653,600	689,800	102,400	37,600	79,900	26,000
FLOWAGE RIGHTS ACQUIRED TO ELEVATION OF	1306.94+	1301.70+	1280.42+	1222.31+	1238.82+	1198.75+
MAXIMUM ELEVATION EVER ATTAINED	1303.39	1297.88	1277.92	1224.82	1234.56	1195.05
NUMBER OF TIMES UPPER OPERATING LIMIT HAS BEEN EXCEEDED	2	0	18	18	0	8
NO TIMES FLOWAGE LIMITS HAVE BEEN EXCEEDED	0	0	0	1	0	0
MAXIMUM ELEVATION ATTAINED 1950	1303.17	1296.81	1277.39	1224.82	1231.41	1195.01
RESERVOIR IN OPERATION	1884	1884	1884	1895	1886	1912

STAGES IN USE PRIOR TO JULY 1973						
RESERVOIR	WINNI-BIGOSHISH	LEECH	POKEGAMA	SANDY	PINE	GULL
NORMAL SPRING STAGE (DATE)	8.0 (3 1)	0.5 (3 1)	6.0 (3 15)	7.0 (2 15)	11.0 (2 15)	5.0 (2 15)
DESIRABLE SUMMER RANGE	10.0-10.5	1.8-2.2	8.75-9.25	8.75-9.25	12.75-13.25	6.0-6.25
ORIGINAL OPERATING LIMITS	0'-14.2'	-0.5'-5.24'	4.5'-12'	0.6'-11	1.3'-18.5'	1.0'-7.0'
CAPACITY, ORIGINAL OPERATING LIMITS AC-FT	967,900	743,300	120,800	78,700	178,900	70,800
PRESENT OPERATING LIMITS	6'-14.2'	0'-5.24'	6'-12'	7'-11'	9-15.0	5'-7'
PRESENT ORDINARY OPERATING LIMITS	8'-12'	0.5'-3.0'	6'-10'	7'-11'	10'-14'	5'-7'
DESIRABLE OPERATING LIMITS	8'-10.5'	0.5'-3.0'	7'-10'	7'-11'	11'-14'	5'-7'
CAPACITY, PRESENT OPERATING LIMITS AC-FT	653,600	689,800	102,400	37,600	79,900	26,000
FLOWAGE RIGHTS ACQUIRED TO STAGE OF	18'+	9'+	16'+	15'+	22.5'+	11.0'+
MAXIMUM STAGE EVER ATTAINED	14.45'	5.18'	13.50'	17.51'	18.24'	7.3'
NUMBER OF TIMES UPPER OPERATING LIMIT HAS BEEN EXCEEDED	2	0	18	18	0	8
NO. TIMES FLOWAGE LIMITS HAVE BEEN EXCEEDED	0	0	0	[illegible]	0	[illegible]
MAXIMUM STAGE ATTAINED IN 1950	14.23'	4.11'	12.97'	17.51	15.09'	7.28'
ZERO OF GAGE:						
(U.S.E. DATUM)	1290.08'	1293.76'	1265.27'	1209.00	1218.[illegible]	1190.00'
(M.S.L. 1912 ADJ.)	1289.47'	1293.23'	1264.89'	1207.70'	---	1188.14'
(M.S.L. 1929 ADJ.)	1288.94'	1292.70'	1264.42'	1207.[illegible]	1216.32'	1187.75'
RESERVOIR IN OPERATION	1884	1884	1884	1895	1886	1912
TOP OF PIERS	15.42	6.84	14.0	14.0	19.5	10.0
SILL	-4.78	-4.96	0.00	0.00	+0.33	+1.[illegible]

Table B-1 - Regulation schedule - Winnibigoshish Dam and Reservoir

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup (1 Oct-1 Mar)	Winter drawdown	1298.44-1296.94	The Water Control Section shall compute the discharge required to lower the pool to spring level, 1296.94 elevation, before the beginning of the spring breakup, usually about 1 April. Periodic checks of inflow shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until spring runoff starts. *The State of Minnesota's plan of operation requires the discharge to be 100 cfs if the elevation is below 1296.94.
Spring breakup period	Storing spring runoff	1296.94-1303.14	Sufficient runoff, if available, must be stored to fill the reservoir to the desired summer range, 1297.94 to 1298.44 (changed from 1298.94-1299.44 in April 1976 for a 5-year trial period), and the storage capacity shall be utilized, if necessary, to prevent or reduce damages to downstream stations, primarily in the Aitkin area. When the breakup begins, reduce discharge to 100 cfs and store balance of inflow. If desired summer range is reached and no danger of flooding exists downstream, discharge inflow. Inflows shall be stored as long as the stage at Aitkin is at or above 15.0 feet, flood stage. However, if Winnibigoshish pool should reach 1303.14 elevation, maximum operating limit, increase discharge to inflow. If the inflow becomes greater than the discharge capacity of the dam, the dam shall be completely opened, and open river conditions will exist until regulation at the dam is again possible. Discharge shall be governed by conditions at Aitkin until spring breakup is completed. *The State of Minnesota's plan of operation limits the maximum discharge to 4,500 cfs if the reservoir is above the desired maximum elevation of 1300.94.

Table B-1 - Regulation schedule - Winnibigoshish Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
End of spring breakup to about 1 July	Bringing reservoir to desired summer range	1303.14 to (1297.94-1298.44)	After it is no longer necessary to store runoff for downstream damage prevention, the Water Control Section shall compute the discharge required to raise or lower the pool as necessary to bring the reservoir to the desired summer range by about 1 July, if possible.
About 1 July to Labor Day	Normal summer operation	1297.94-1298.44	By the operation of the slide gates and the addition or removal of bulkheads, if necessary, maintain pool at desired summer range until winter drawdown begins. *The State of Minnesota's plan of operation requires the discharge to be 100 cfs if the elevation is below 1299.19.
Flood control			
Summer	Large runoff from intense or prolonged rainfall or winter thaw	1297.94-1303.14	The operation is the same as that for storing the spring runoff during the spring breakup period.
Fall		1296.94-1303.14	
Winter		1296.94-1303.14	
Water supply and conservation			
Drought	Very low inflows	1298.44-1294.94 or lower if necessary	If inflows become so low that the reservoir must be lowered below desired elevation, so far as practicable the reservoir shall be maintained above an elevation of 1294.94. The flow shall be governed by the Secretary of the Army's regulation that the average annual discharge shall not be reduced below 150 cfs. If the reservoir is at or below the minimum elevation of 1294.94, no discharge other than the minimum specified above shall be permitted except such increased discharge as may specifically be directed by the Chief of Engineers.

Table B-1 - Regulation schedule - Winnibigoshish Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Water supply and conservation (cont)			
			*The State of Minnesota's plan of operation requires the discharge to be 50 cfs if the elevation is below 1294.64, minimum elevation, and 100 cfs if the elevation is between 1294.64 and 1299.19. When greater flows are required at the minimum elevation, the discharge may be increased if authorized by the Commissioner of the Department of Natural Resources, and the maximum shall be 900 cfs.

* The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purpose of navigation and flood control.

Current Department of Natural Resources Recommendations for Operating Winnibigoshish Reservoir. When conditions will permit, any increase or decrease in discharge from Winnibigoshish Reservoir should be made so that the rate of outflow does not change more than 50 cfs each day, when the total change is to be less than 300 cfs, or so that the rate of outflow does not change more than 100 cfs each day when the total change is to be more than 300 cfs. A change at a rate of 100 cfs every other day will be acceptable, as a substitute for a change of 50 cfs each day.

Minnesota Department of Natural Resources regulation of Winnibigoshish Reservoir

Elevation in feet 1929 adj.	Maximum discharge in cfs if authorized by the Commissioner of the Department of Natural Resources
1289.94	50
1290.94	100
1291.94	300
1292.94	500
1293.94	700
1294.94	900
1295.94	1,100
1296.94	2,100
1297.94	3,100
1298.94	4,500
1299.09**	4,500
1299.19	4,500

** Most desirable elevation for recreational purposes.

Table B-2 - Regulation schedule - Leech Lake Dam and Reservoir

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup (1 Oct - 1 Mar)	Winter drawdown	1294.70-1293.20	The Water Control Section shall compute the discharge required to lower the pool to spring level, 1293.20 elevation, before the beginning of the spring breakup, usually about 1 April. Periodic checks of inflow shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until spring runoff starts. *The State of Minnesota's plan of operation requires the discharge to be 100 cfs if elevation is below 1294.70.
Spring breakup period	Storing spring runoff	1293.20-1297.94	Sufficient runoff, if available, must be stored to fill the reservoir to the desired summer range, 1294.50 to 1294.90, and the storage capacity shall be utilized, if necessary, to prevent or reduce damages to downstream stations, primarily in the Aitkin area. When the breakup begins, reduce discharge to 100 cfs and store balance of inflow. If desired summer range is reached and no danger of flooding exists downstream, discharge inflow. Inflows shall be stored as long as the stage at Aitkin is at or above 15.0 feet, flood stage. However, if Leech Lake pool should reach elevation 1297.94, maximum operating limit, increase discharge to inflow. If the inflow

Table B-2 - Regulation schedule - Leech Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
Spring breakup period (cont)			becomes greater than the discharge capacity of the dam, the dam shall be completely opened, and open river conditions will exist until regulation at the dam is again possible. Discharge shall be governed by conditions at Aitkin until the spring breakup is completed. *The State of Minnesota's plan of operation limits the maximum discharge to 1,700 cfs if the reservoir is above the desired maximum elevation of 1296.20.
End of spring breakup to about 1 July	Bringing reservoir to desired summer range	1297.94 to (1294.50-1294.90)	After it is no longer necessary to store runoff for downstream damage prevention, the Water Control Section shall compute the discharge required to raise or lower the pool as necessary to bring the reservoir to the desired summer range by about 1 July, if possible.
About 1 July to Labor Day	Normal summer operation	1294.50-1294.90	By operating the slide gates, regulate the outflow to maintain pool at desired summer range until winter drawdown begins. *The State of Minnesota's plan of operation requires the discharge to be 100 cfs if the pool is below 1294.70.
Flood control			
Summer	Large run-off from intense or	1294.50-1297.94	The operation is the same as that for storing the spring runoff during the spring breakup period.
Fall	prolonged rainfall or	1293.20-1297.94	
Winter	winter thaw	1293.20-1297.94	

Table B-2 - Regulation schedule - Leech Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Water supply and conservation			
Drought	Very low inflows	1294.90-1292.70 or lower if necessary	If flows become so low that the reservoir must be lowered below desired stage, so far as practicable the reservoir shall be maintained above an elevation of 1292.70. The flow shall be governed by the Secretary of the Army's regulation that the average annual discharge shall not be reduced below 70 cfs. If the reservoir is at or below the minimum elevation of 1292.70, no discharge other than the minimum specified above shall be permitted except such as may specifically be directed by the Chief of Engineers. *The State of Minnesota's plan of operation requires the discharge to be 50 cfs if the elevation is below 1292.70; minimum elevation is between 1292.70 and 1294.70. When greater flows are required at the minimum elevation, the discharge may be increased if authorized by the Commissioner of the Department of Natural Resources, and the maximum shall be 150 cfs.

* The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purpose of navigation and flood control.

Table B-2 - Regulation schedule - Leech Lake Dam and Reservoir (cont)

..rrent Department of Natural Resources Recommendations for Operating Leech Lake Reservoir. Whenever conditions will permit, any increase or decrease in discharge from Leech Lake Reservoir should be made so that the rate of outflow does not change more than 50 cfs each day, or 100 cfs every other day, when the total change is to be less than 300 cfs, or so that the rate of outflow does not change more than 100 cfs each day, when the total change is to be more than 300 cfs.

Minnesota Department of Natural Resources regulation of Leech Lake Reservoir

Elevation in feet 1929 adj	Maximum discharge in cfs if authorized by the Commissioner of the Department of Natural Resources
1291.70	50
1292.20	100
1292.70	150
1293.20	200
1293.70	400
1294.20	600
1294.70**	1,100
1295.20	1,400
1295.70	1,500
1296.20	1,600
1296.70	1,700
1297.20	1,700

** Most desirable elevation for recreational purposes.

Table B-3 - Regulation schedule - Pokegama Dam and Reservoir

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup (1 Oct - 15 Mar)	Winter drawdown	1273.67-1270.42	The Water Control Section shall compute the discharge required to lower the pool to spring level, 1270.42 elevation, before the beginning of the spring breakup, usually about 1 April. Periodic checks of inflow shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until the spring runoff starts. Should the level at Days High Landing recede to elevation 1271.5 during the drawdown period before an elevation of 1270.42 occurs at Pokegama Lake, maintain elevation 1271.50 at Days High Landing by maintaining an elevation higher than 1270.42 at Pokegama. *The State of Minnesota's plan of operation limits the discharge from Pokegama Reservoir if the elevation is below 1270.42 or below any desired elevation above 1270.42 to the sum of the discharges from Winnibigoshish and Leech Reservoirs; but when Pokegama Reservoir is above the desired elevation, the discharge need not be limited by the discharges from Winnibigoshish and Leech Reservoirs.

Table B-3 - Regulation schedule - Pokegama Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
Spring breakup period	Storing spring runoff	1270.42-1278.42	The discharges from Pokegama and Sandy Lake Reservoirs shall be regulated so that the ultimate elevations at these two reservoirs and at Aitkin shall result in elevations that correspond to the guide curve for spring floods. Should the elevation at Pokegama Reservoir reach 1278.42, the dam must be completely opened, and open river conditions will exist until the pool drops to elevation 1277.92. At this elevation, operation should again be based on the guide curve, if possible. *The State of Minnesota's plan of operation limits the maximum discharge to 5,500 cfs if the reservoir is above the desired maximum elevation of 1276.42.
End of spring breakup to about 1 July	Bringing reservoir to desired summer range	1278.42 to (1273.17-1273.67)	On the recession of the inflow, the elevation in Pokegama and Sandy Reservoirs shall be governed by the guide curve, if possible, until the pool has dropped to the desired summer elevation. (There have been only a few times since operation started that these reservoirs have not filled to above the desired summer elevation.)

Table B-3 - Regulation schedule - Pokegama Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
About 1 July to Labor Day	Normal summer operation	1273.17-1273.67	Regulate the outflow through the sluiceways to maintain pool at the desired summer range, if possible, until winter drawdown begins.
Flood control			
Summer	Large runoff from intense or prolonged rainfall or winter thaw	1273.17-1278.42	The operation is the same as that for storing the spring runoff during the spring breakup period except, in the summer months, use the guide curve for summer months.
Fall		1270.42-1278.42	
Winter		1270.42-1278.42	
Water supply and conservation			
Drought	Very low inflows	1273.67-1270.42 or lower if necessary	If inflows become so low that the reservoir must be lowered below the desired elevation, so far as practicable the reservoir shall be maintained above an elevation of 1270.42. The flow shall be governed by the Secretary of the Army's regulation that the average annual discharge shall not be reduced below 200 cfs. If the reservoir is at or below the minimum elevation of 1270.42, no discharge other than the minimum specified above shall be permitted except such increased discharge as may specifically be directed by the Chief of Engineers.

* The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purposes of navigation and flood control.

Table B-4 - Regulation schedule - Sandy Lake Dam and Reservoir

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup (1 Oct - 15 Feb)	Winter drawdown	1216.56-1214.31	The Reservoir Regulating Section shall compute the discharge required to lower the pool to minimum operating limit, elevation 1214.31, before the beginning of the spring breakup, usually about 1 April. Periodic checks of inflow shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until spring runoff starts. *The State of Minnesota's plan of operation requires the discharge to be 20 cfs if the elevation is below 1216.31.
Spring breakup	Storing	1214.31-1221.31	The discharges from Sandy Lake and Pokegama Reservoirs shall be regulated so that the ultimate elevations at these two reservoirs and at Aitkin shall result in elevations that correspond to the guide curve for spring floods. Should the elevation at Sandy Reservoir exceed 1221.31, the dam must be completely opened, and open river conditions will exist until the pool drops below 1221.31, maximum and ordinary operating limit. At this elevation, operation should again be based on the guide curve, if possible. *The State of Minnesota's plan of operation limits the maximum discharge to 3,800 cfs if the reservoir is at or above the desired maximum elevation of 1218.31.

Table B-4 - Regulation schedule - Sandy Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
End of spring breakup to about 15 May	Bringing reservoir to desired summer range	1221.31 to (1216.06-1216.56)	On the recession of the inflow, the elevation in Sandy and Pokegama Reservoirs shall be governed by the guide curve, if possible, until the pool has dropped to the desired elevation. (There have been only a few times since operation started that Sandy Reservoir has not filled to above the desired summer elevation.)
About 15 May to Labor Day	Normal summer operation	1216.06-1216.56	Regulate the outflow through the lift gates and sluiceways, if necessary, to maintain pool at the desired summer range, if possible, until winter drawdown begins. *The State of Minnesota's plan of operation requires the discharge to be 20 cfs if the elevation is below 1216.31.
Flood control			
Summer Fall Winter	Large runoff from intense or prolonged rainfall or winter thaw	1216.06-1221.31 1214.31-1221.31 1214.31-1221.31	The operation is the same as that for storing the spring runoff during the spring breakup period except, if during the summer months, use the guide curve for summer months.
Water supply and conservation			
Drought	Very low inflows	1216.56-1214.31 or lower if necessary	If inflows become so low that the reservoir must be lowered below the desired elevation, so far as practicable the reservoir shall be maintained above an elevation of 1214.31.

Table B-4 - Regulation schedule - Sandy Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Water supply and conservation (cont)			
			The flow shall be governed by the Secretary of the Army's regulation that the average annual discharge shall not be reduced below 80 cfs. If the reservoir is at or below the minimum elevation of 1214.31, no discharge other than the minimum specified above shall be permitted except such increased discharge as may specifically be directed by the Chief of Engineers. *The State of Minnesota's plan of operation requires the discharge to be 10 cfs if the elevation is below 1214.31, minimum elevation, and 20 cfs if the elevation is between 1214.31 and 1216.31. When larger flows are required at the minimum elevation, the discharge may be increased if authorized by the Commissioner of the Department of Natural Resources and the maximum shall be 200 cfs.

*The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purposes of navigation and flood control.

Minnesota Department of Natural Resources regulation of Sandy Lake Reservoir

Elevation in feet 1929 adj.	Maximum discharge in cfs if authorized by the Commissioner of the Department of Natural Resources
1207.31	10
1208.31	20
1209.31	40
1210.31	60
1211.31	80
1212.31	100
1213.31	150
1214.31	200
1215.31	400
1216.31**	1,400
1217.31	2,400
1218.31	3,800
1219.31	3,800

** Most desirable elevation for recreational purposes.

Table B-5 - Regulation schedule - Pine River Dam and Reserv[illegible]

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup	Winter drawdown	1229.57-1227.32	The Water Control Section shall compute the discharge required to lower the pool to spring level, 1227.32 elevation, before the beginning of the spring breakup, usually about 1 April. Periodic checks of [illegible] shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until spring runoff starts. *The State of Minnesota's plan of operation requires the discharge to be 30 cfs if the elevation is between [illegible] and [illegible].
Spring breakup period	Storing spring runoff	1227.32-1231.32	When the breakup begins, reduce the outflow to [illegible] and store the balance of the inflow until the pool reaches an elevation of [illegible], desirable summer level. [illegible] the pool continues to rise above [illegible], [illegible] within the reservoir and downstream conditions shall govern the amount of the discharge. The situation at stations on the Mississippi River from Fort [illegible] to the [illegible] Cities [illegible] be considered in determining the outflow. If protection from [illegible] is needed at any of these stations, the inflow shall be stored as necessary until maximum operating limit, 1231.[illegible] elevation, is [illegible].

Table B-5 - Regulation schedule - Pine River Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
Spring breakup period (cont)			At this elevation, increase discharge to inflow. If the inflow becomes greater than the discharge capacity of the dam, the dam shall be completely opened, and open river conditions will exist until regulation at the dam is again possible. Discharge shall be governed by damage within the reservoir and downstream conditions until the spring breakup is completed. *The State of Minnesota's plan of operation limits the maximum discharge to 2,500 cfs if the reservoir is above the desired maximum elevation of 1230.32. After the reservoir has filled to an elevation of at least 1229.32, and it is no longer necessary to store runoff for downstream damage prevention, the Water Control Section shall compute the discharge required to lower the pool to the desired summer range (1229.07-1229.57) by about 15 May, if possible. (There have been only a few times since operation started that this reservoir has not filled to above the desired summer elevation.)
About 15 May to Labor Day	Normal summer operation	1229.07-1229.57	By the operation of the sluice gates and the addition or removal of bulkheads, if necessary, maintain pool at desired summer range until winter drawdown begins. *The State of Minnesota's plan of operation requires the discharge to be 30 cfs if the elevation is below 1229.32.

Table B-5 - Regulation schedule - Pine River Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Flood control			
Summer	Large runoff from intense	1229.07-1231.32	The operation is the same as that for storing the spring runoff during the spring breakup period.
Fall	or prolonged rainfall or	1227.32-1231.32	
Winter	winter thaw	1227.32-1231.32	
Water supply and conservation			
Drought	Very low inflows	1229.57-1225.32 or lower if necessary	If inflows become so low that the reservoir must be lowered below the desired elevation, so far as practicable the reservoir shall be maintained above an elevation of 1225.32. The flow shall be governed by the Secretary of the Army's regulation that the average annual discharge shall not be reduced below 90 cfs. If the reservoir is at or below the minimum elevation of 1225.32, no discharge other than the minimum specified above shall be permitted except such increased discharge as may specifically be directed by the Chief of Engineers. *The State of Minnesota's plan of operation requires the discharge to be 15 cfs if the elevation is below 1225.32 minimum elevation, and 30 cfs if the elevation is between 1225.32 and [illegible]. When larger flows are required at the minimum elevation, the discharge may be increased if authorized by the Commissioner of the Department of Natural Resources and the [illegible] shall be [illegible].

* The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purposes of navigation and flood control.

Minnesota Department of Natural Resources regulation of Pine River Reservoir	
Elevation in feet (1929 adj)	Maximum discharge in cfs if authorized by the Commissioner of the Department of Natural Resources
1217.32	15
1218.32	30
1219.32	40
1220.32	50
1221.32	60
1222.32	70
1223.32	80
1224.32	90
1225.32	100
1226.32	200
1227.32	300
1228.32	400
1229.32**	500
1230.32	2,500
1231.32	2,500

** Most desirable elevation for recreational purposes.

Table B-6 - Regulation schedule - Gull Lake Dam and Reservoir

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation			
After Labor Day to spring breakup (1 Oct - 15 Feb)	Winter drawdown	1194.00-1192.75	The Water Control Section shall compute the discharge required to lower the pool to minimum operating limit, 1192.75, before the beginning of the spring breakup, usually about 1 April. Periodic checks of inflow shall be made and outflow adjusted as necessary. If the drawdown is completed before the breakup begins, discharge inflow until spring runoff starts. *The State of Minnesota's plan of operation requires the discharge to be 20 cfs if the elevation is below 1192.75.

Table B-6 - Regulation schedule - Gull Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
Spring breakup period	Storing spring runoff	1192.75-1194.75	When the breakup begins, obtain runoff from plate 49 and compute inflow. It is desirable to raise the pool to summer range, 1193.75 to 1194.00 elevation, by 15 May. From inflow and storage change, compute outflow. When the pool reaches 1193.75 to 1194.00, discharge inflow if downstream conditions permit. If it is necessary to store inflows for downstream protection, allow the pool to rise to maximum and ordinary operating limit, 1194.75 elevation, and at this elevation discharge inflow. If the inflow becomes greater than the discharge capacity of the dam, the dam shall be completely opened, and open river conditions will exist until regulation at the dam is again possible. Thereafter, discharge shall be governed by downstream conditions until the spring breakup is completed. *The State of Minnesota's plan [illegible] operation limits the maximum discharge [illegible] 1,400 [illegible] when the elevation is above [illegible] desired maximum elevation [illegible] 1194.75.

Table B-6 - Regulation schedule - Gull Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Routine operation (cont)			
End of spring breakup to about 15 May	Bringing reservoir to desired summer range	1194.75 to (1193.75-1194.00)	After the reservoir has been filled to the desirable summer range, 1193.75 to 1194.00 elevation, and it is no longer necessary to store runoff for downstream damage prevention, discharge inflow. If it has been necessary to fill the reservoir above the desired summer range, the Water Control Section shall determine the discharge required to gradually lower the pool to the summer range at a rate that will not endanger spawning fish and nesting waterfowl.
About 15 May to Labor Day	Normal summer operation	1193.75-1194.00	Regulate the outflow to maintain the pool at the desired summer range, 1193.75 to 1194.00 elevation, if possible, until winter drawdown begins. *The State of Minnesota's plan of operation requires the discharge to be 20 cfs if the elevation is below 1193.85.
Flood control			
Summer	Large runoff from intense or prolonged rainfall or winter thaw	1193.75-1194.75	The operation is the same as that for storing the spring runoff during the spring breakup period.
Fall		1192.75-1194.75	
Winter		1192.75-1194.75	

Table B-6 - Regulation schedule - Gull Lake Dam and Reservoir (cont)

Regulation schedule	Condition	Reservoir elevation (feet)	Operation
Water supply and conservation			
Drought	Very low inflows	1194.00-1192.75 or lower if necessary	If inflows become so low that the reservoir must be lowered below desired stage, so far as practicable the reservoir shall be maintained above an elevation of 1192.75. The flow shall be governed by the Secretary of the Army's regulation that the annual average discharge shall not be reduced below 30 cfs. If the reservoir is at or below the minimum elevation of 1192.75, no discharge other than the minimum specified above shall be permitted except such increased discharge as may specifically be directed by the Chief of Engineers. *The State of Minnesota's plan of operation requires the discharge to be 10 cfs if the elevation is below 1192.75, minimum elevation, and 20 cfs if the elevation is between 1192.75 and 1193.85. When greater flows are required at the minimum elevation, the discharge may be increased if authorized by the Commissioner of the Department of Natural Resources and the maximum shall be 100 cfs.

* The State of Minnesota's plan of operation shall be effective only when the reservoirs are not functioning for the primary purpose of navigation and flood control.

Minnesota Department of Natural Resources regulation of Gull Lake Reservoir

Elevation in feet	Maximum discharge in cfs if authorized by the Commissioner of the Department of Natural Resources
1190.75	10
1191.25	20
1191.75	40
1192.25	60
1192.75	100
1193.25	200
1193.75	400
1193.85**	
1194.25	600
1194.75	1,000
1195.25	1,400

** Most desirable stage for recreational purposes.

STAGE 3 REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

A P P E N D I X C

FLOODPLAIN REGULATION, FLOOD INSURANCE, AND LAKESHORE LAND USE REGULATIONS

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

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PLATES

PURPOSE AND SCOPE

This section is provided to familiarize study area officials with floodplain management measures available for reducing flood losses and with the area's relationship to existing and future flood loss potential. The combined solutions, involving nonstructural and structural measures, are all required to insure proper management of the floodplain and to minimize future flood losses. This section describes measures local governments can take to control land use and development and thus reduce the flood threat in the residual floodplain not afforded flood protection.

AVAILABLE DATA

Detailed information concerning the flood situation in the study area includes the following:

a. A June 1975 Flood Plain Information Report for the Mississippi River and Ripple River at Aitkin, Minnesota, was prepared by the St. Paul District, Corps of Engineers. This report has detailed floodplain and profile maps for the Aitkin area from river mile 1046.8 to 1061.6 on the Mississippi River and from river mile 0 to 5.7 on the Ripple River. The report shows this information for the 100-year and standard project floods.

b. A review draft, "Flood Insurance Study and Flood Insurance Rate Map," by the U.S. Department of Housing and Urban Development, Federal Insurance Administration, dated May 1977, summarizes flood hazard information for the unincorporated areas of Itasca County, Minnesota. Detailed study areas include Pokegama Lake, Blackwater Lake, Cutoff Lake, Little Jay Gould Lake, Jay Gould Lake, and the Mississippi River reaches from the west Grand Rapids city limits to the Pokegama Lake Dam, and from the Pokegama Lake Dam to Blackwater Lake. Other Mississippi River reaches, the Prairie River, and Swan River were studied by approximate methods.

c. A current study by the Department of Housing and Urban Development will establish actuarial rates for both urban and rural Aitkin County flood prone areas by late 1979 or early 1980.

d. A Flood-Prone Area Map for the Cohasset and Grand Rapids areas prepared by the U.S. Geological Survey (1974 and 1969).

e. A Flood Hazard Boundary Map for Grand Rapids, prepared by the Federal Insurance Administration, 1976.

f. A Flood Hazard Boundary Map for the city of Warba, prepared by the Federal Insurance Administration, 1975.

g. Detailed information concerning floodplain rules and regulations is contained in chapter 7 of "Rules and Regulations of the Department of Natural Resources," dated October 1970 and established in accordance with section 104.05 of the 1969 Minnesota statutes. This information served as a guide for this appendix.

METHODS OF FLOOD DAMAGE REDUCTION

Land use controls and other measures which can be implemented by local governments and individuals to guide future floodplain developments are as important as structural measures in preventing future flood damages. Before local ordinances can be adopted, technical data must be developed for delineation of floodplains and floodways along watercourses. The local ordinances are designed to include provisions for preserving the capacity of the floodplain to carry regional flood flows, minimizing flood hazards, and regulating the use of floodplain lands. In Minnesota, local floodplain management ordinances and subsequent modifications are subject to approval of the Commissioner of the Department of Natural Resources. Methods of regulating floodplain land use and development and other possible means of reducing or preventing future flood damages are described in later paragraphs.

CONTROL OVER THE LAND

Floodplain regulations imply that communities adopt and use legal tools to control the extent and types of future development permitted in floodplains. For these controls to be effective, the public must understand the flood problem, the degree of risk, and the methods that can be used to control land use.

Designated Floodways and Encroachment Lines

A designated floodway is the area of the channel and those portions of the floodplain adjoining the channel which are reasonably required to carry the regional flood. The regional flood is one that can reasonably be expected to occur in Minnesota on an average frequency of 1 percent or 100-year recurrence interval. Any proposed flood control works in urban area floodplains are to be constructed to 3 feet above the regional flood elevation or equal to the standard project flood elevation, whichever is greater. Encroachment lines are the lateral boundaries of the floodway, one on each side of the channel. In general, neither construction nor land filling which would interfere with passage of floodwaters as specified in State regulations should be permitted between these defined encroachment lines. A schematic drawing of a typical stream floodplain is shown on plate C-1.

Zoning

Zoning is the legal tool used to implement and enforce the detailed plans resulting from the planning program. It is used by communities, counties, and State agencies to control and direct use and development of land and property within their jurisdiction. Zoning insures the safekeeping of property for public health and welfare and the best use of available land. Division of communities into various zones should be the result of a comprehensive planning program for the entire area. Designated floodways may be zoned for passing floodwaters and for other limited uses that do not conflict with that primary purpose. Zoning may also establish regulations for floodplain areas outside the floodway, including designated elevations below which certain types of development cannot be constructed.

Subdivision Regulations

A subdivision is a tract of land divided into lots for sale or building development. Local governments use subdivision regulations to specify the manner in which land may be divided. These regulations state the requirements for width of streets, curb and gutter, size of lots, elevation of land, freedom from flooding, size of floodways, and other points pertinent to the welfare of the community. Not only can public health and welfare benefit, but municipal costs such as maintenance of streets and utilities can be reduced. Subdivision regulations provide an efficient means of controlling construction in presently undeveloped floodplain areas. The following typical provisions, if added to local regulations, would help prevent flood damage:

a. Show the extent of the floodplain on subdivision maps.

b. Show the floodway limits or encroachment lines.

c. Prohibit fill in the floodway that would restrict flow.

d. Require that subdivision roads be above the elevation of a selected flood level.

e. Require that each lot contain a building site with an elevation above a selected flood level.

Building Codes

A building code is a set of regulations adopted by a local governing body. The code sets forth standards for construction of buildings and other structures to protect the health, safety, and general welfare of the public. A well-written and properly enforced building code can effectively reduce damages to buildings in the floodplain. A few of the requirements which should be specified in a building code to reduce flood damages are:

a. Prevent flotation of buildings from their foundations by requiring proper anchorage.

b. Establish basement elevations and minimum first-floor elevations consistent with potential floods.

c. Require sufficient structural strength to withstand water pressure or high velocity of flowing water.

d. Restrict the use of materials which deteriorate rapidly when exposed to water.

e. Prohibit equipment that might be hazardous to life when submerged, such as chemical storage tanks, boilers, or electrical equipment.

FLOOD PROOFING

Flood proofing is a combination of structural changes and adjustments to properties subject to flooding, primarily meant to reduce or eliminate flood damages. Although more simply and economically applied to new construction, flood proofing is also applicable to existing facilities. It has promise in one or more of the following situations:

a. Moderate flooding with low stage, low velocity, and short duration is experienced.

b. Traditional flood protection is not feasible.

c. Individuals desire to solve their flood problems without collective action or collective action is not possible.

d. Activities dependent on river or stream locations need some degree of protection.

e. A resource manager desires a higher degree of protection than that provided by a flood control project.

Plates C-2 and C-3 illustrate common flood proofing actions used to protect buildings in the floodplain.

FLOOD WARNING AND FORECASTING SERVICES

Flood warning and forecasting services for the study area are provided by the National Weather Service Forecast Office in Minneapolis, Minnesota. Daily stage readings and crest forecasts are available at that office for dissemination to the public through Associated Press and United Press International wires or via local wires and telephone to newspapers, radio and television stations, the State Civil Preparedness Office, and the St. Paul District, Corps of Engineers. In general, flood stages and crest forecasts for the area are provided 24 to 36 hours in advance. However, the warning time varies depending on the intensity, duration, distribution pattern, antecedent conditions, and time of occurrence of rainfall. In the case of snowmelt flooding, accurate advance assessment of the potential for severe area flooding could prevent loss of life and possibly reduce property losses. Sufficient warning time is available for snowmelt and rainstorm peak runoff in the Mississippi River Headwaters Lakes and Aitkin area streams.

TEMPORARY EVACUATION

Temporary evacuation of persons and property from the path of floodwaters is another important aspect of flood loss reduction. When a flood is expected:

a. Buildings can be evacuated.

b. Materials can either be raised above floodwaters or moved to high ground.

c. Emergency protective measures can be undertaken

d. Flood fighting and relief agencies can be notified.

PERMANENT EVACUATION

Permanent evacuation of developed areas subject to inundation involves purchase of lands, removal of improvements, and relocation of the population from such areas. Lands acquired in this manner could be used for hiking trails, parks, or other purposes that would not interfere with flood flows or result in material damage from floods.

OPEN SPACES

Great emphasis is being placed on the growing need for areas for recreation and other open-space uses. Areas adjacent to streams and other bodies of water have a natural attraction and are readily adaptable to recreation. Lands not suitable for facilities requiring permanent structures could be used for parks, picnic areas, and playgrounds. A number of localities throughout the country are using floodplains for such purposes and are reaping secondary benefits from flood damage prevention. Federal grants are available to assist communities with acquisition of open spaces when it is linked with a comprehensive planning program.

URBAN DEVELOPMENT AND RENEWAL

Urban renewal can be used in flood blighted areas that drain the economic life and welfare of the community and do not lend themselves to other methods of regulation and control. The Federal urban renewal program provides substantial assistance to municipalities burdened with such conditions. Federally financed plans for projects provide guidelines for private and governmental financial commitments.

WARNING SIGNS

A method which may be used to discourage development is the erection of flood warning signs in the floodplain area or the prominent posting of previous high water levels. These signs carry no enforcement but simply inform prospective buyers that a flood hazard exists.

CONSTRUCTION FINANCING

The Flood Disaster Protection Act of 1973 requires flood insurance on all Federal or federally assisted financing of buildings in flood prone areas. Flood insurance for individual buildings is obtained from actuarial rates determined from detailed floodplain surveys. The act states that communities that do not participate in the flood insurance program will be ineligible for all Federal loans and grants and mortgage loans from federally insured or regulated lending institutions for the construction or acquisition of buildings in identified floodplains. With this requirement, the Federal Government takes the stand that, for humane and economic reasons, it will not finance a building in a known flood prone area unless it is protected by flood insurance. In this way, new construction in flood hazard areas can be controlled and resulting increases in future flood damages may be prevented.

From 1969 through 31 December 1977, the Federal Flood Insurance Progr.m was administered through a consortium of 132 insurance companies under contract to the Department of Housing and Urban Development. On 1 January 1978, a single firm, Electronic Data Systems, took over the administration of the Federal Flood Insurance Program, under contract with the Department of Housing and Urban Development.

FLOOD INSURANCE

Flood insurance does not prevent or reduce flood damages but, if established on a sound and equitable basis, it could relieve the financial burden of flood damages and provide another supplement to programs for reducing flood damages. However, insurance rates should realistically reflect the flood risk to discourage improper development of floodplains. The Flood Disaster Protection Act of 1973 establishes a program of Federal assistance for flood insurance to be related to a unified national program for floodplain management. The act expands and improves the 1968 Flood Insurance Program by:

a. At least doubling the limits of insurance coverage.

b. Extending the emergency program for 2 years, thus assuring that individuals and communities can continue to obtain flood insurance that would otherwise not be available.

c. Removing the limit on the total amount of insurance which can be written.

d. Creating incentives for flood prone communities to enter the program and thereby make insurance available to the citizens.

e. Requiring insurance on all Federal or federally assisted financing of buildings in flood prone areas.

f. Accelerating the completion of rate studies for flood prone communities.

g. Establishing explicit procedures for communities wishing to appeal, on a technical basis, the Department of Housing and Urban Development's flood elevation determinations for land use purposes.

With these measures the National Flood Insurance Program is able to provide the certainty of financial protection for anyone who decides that it is necessary to build in flood prone areas. Communities are required to strengthen their commitments to flood preventive efforts, thus lessening the disastrous results of flooding and easing the burden on all taxpayers.

The National Flood Insurance Program is divided into two parts: (1) the emergency program and (2) the regular program. Under the emergency program, designated flood hazard communities obtain flood insurance at a flat or subsidized rate. Communities participating in the emergency program must have been involved before 1 July 1975 (later extended to 1 July 1976) to be eligible for future flood disaster relief loans. Communities participating in the regular program use actuarial flood insurance rates determined from detailed floodplain surveys.

Under the emergency program, flood insurance at subsidized rates is available on structures in Minnesota in amounts up to $35,000 for single family dwellings and $100,000 for multifamily and nonresidential structures. Insurance on contents is available up to $10,000 for residential units and $100,000 for nonresidential units.

Under the regular program, coverage up to double the above amounts will be available at subsidized or actuarial rates. Individual counties and communities will participate in the regular flood insurance program using actuarial rates when floodplain surveys are completed and regulations are developed.

BRIDGES

Community expansion brings the desire for more stream crossings. From a construction standpoint, perhaps the most economical method of providing crossings consists of roadways on earth embankments with a small bridge or culvert to pass streamflows. However, this is often the least desirable

method from a flood damage point of view. If the structure is kept at a low elevation, it is frequently overtopped and fails to serve its purpose. If the roadway is kept high above the floodplain, it will act as a dam and increase flood stages upstream unless the waterway opening is adequate. Therefore, all future stream crossings in the study area should be designed to provide adequate waterway openings, overhead clearances, and roadway heights.

FLOODPLAIN REGULATIONS

The State of Minnesota has a floodplain regulation law that requires counties and cities in flood prone areas to adopt, enforce, and administer sound floodplain management ordinances within their jurisdiction whenever sufficient technical information is available for delineation of floodplains and floodways on their watercourses. Sufficient detailed technical information is available to properly define the flood hazard areas and to develop floodplain regulations for the following locations in the study area: cities of Aitkin, Cohasset, Grand Rapids, and Warba, Minnesota.

Waterways and adjacent wetlands are under the jurisdiction of the Corps of Engineers for placement of dredged or fill material. The permit authority stems from Section 404 of the Clean Water Act. Anyone wishing to place dredged or fill material in any of the qualifying streams or adjoining wetlands should contact the St. Paul District Regulatory Functions Branch. Any required section 404 permit application would be processed jointly with the appropriate State permit application. Some projects may be covered by a nationwide permit and this could be confirmed by the St. Paul District on a case-by-case basis.

FLOODPLAIN REGULATION AND FLOOD INSURANCE AS AN ALTERNATIVE TO STRUCTURAL IMPROVEMENTS

Floodplain regulation prevents or reduces future flood damages by regulating new development in existing floodplain areas. [illegible] insurance does not prevent flood damages but only reimbur[illegible]

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82 6/8

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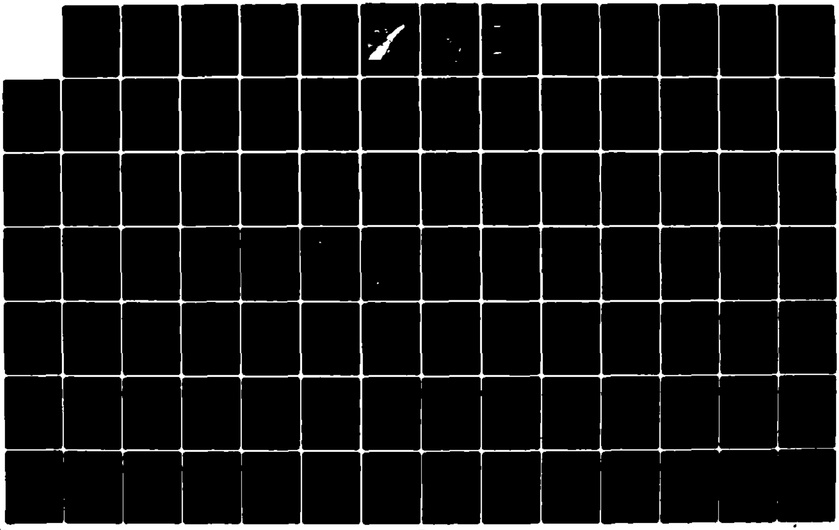

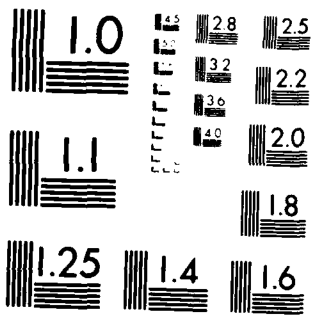
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owners for losses sustained from floods. Flood insurance could provide a limited form of protection for flood prone sections of the study area, especially if used in conjunction with floodplain regulation on new development.

Floodplain regulation and flood insurance, plus existing structural improvements and flood forecasting and warning services, provide the current flood reduction plan for the study area because of the high costs of any structural solutions.

SHORELAND REGULATIONS IN THE MISSISSIPPI RIVER HEADWATERS AREA

Regulations which control lakeshore land use in the Mississippi River Headwaters area include: the 1969 Shoreland Management Act, Minnesota's lake classification system, individual county zoning ordinances, and Federal navigation and pollution control laws.

The 1969 Minnesota Shoreland Management Act outlines the minimum standards and criteria for management of the lakeshores. The enforcement function is delegated to local government units, which must adopt and implement ordinances to meet these minimum standards. State participation in the process occurs only when the local governments have failed to meet and enforce the minimum standards.

The Minnesota Department of Natural Resources rarely intervenes in the local enforcement of the Shoreland Management Act. Each county has its own ordinances and field inspectors who have complete control over individual permits, exceptions, and variances. The Department steps in on decisions involving existing substandard sewage treatment.

The Shoreland Management Act affects all land within 1,000 feet of a lake, pond, or flowage and within 300 feet of a river or stream. The act provides for classification of the lakes on the basis of size,

crowding potential, amount and type of existing development, existing natural characteristics, and county and regional public water needs. The four classes of lakes are: Natural Environment Lakes and Streams, Recreational Development Lakes and Streams, General Development Lakes and Streams, and Critical Lakes.

Natural Environment waters are assigned the most stringent set of development standards. Heavy development would adversely affect the resource potential of these waters. Small lakes, shallow lakes, or those with extensive areas of low swampy shorelines are classified as Natural Environment waters.

Recreational Development waters are assigned the middle set of development standards. They are usually moderately developed and have physical characteristics more suited to development than Natural Environment waters.

General Development waters are densely developed, multiple-use waters that carry the least restrictive development criteria. Since these waters are already heavily developed, the zoning restrictions applied must be reasonably consistent with the existing development patterns.

Critical Lakes are badly deteriorated lakes which cannot be reasonably managed in any of the other public water classes. Until specific standards are developed for each lake, Critical Lakes will be subject to the standards applied to Natural Environment waters.

The six headwaters lakes are classified as General Development waters because of their present high-density, multiple-use development. The zoning provisions for General Development are the least restrictive of the four classes and provide guidance for any future growth

or construction which requires a location on public waters. Specifically, the provisions state that minimum lot size shall be 20,000 square feet and lots shall be at least 100 feet wide at the building line and 100 feet wide at the water line. The total area of all structures shall not equal or exceed 30 percent of the lot. Building setback must be at least 75 feet from the normal high watermark. This setback applies to all structures except boathouses, piers, and docks. The setback for septic tanks and soil absorption systems must be at least 100 feet. The individual county ordinances must meet the minimum State standards and, in some cases, are more severe.

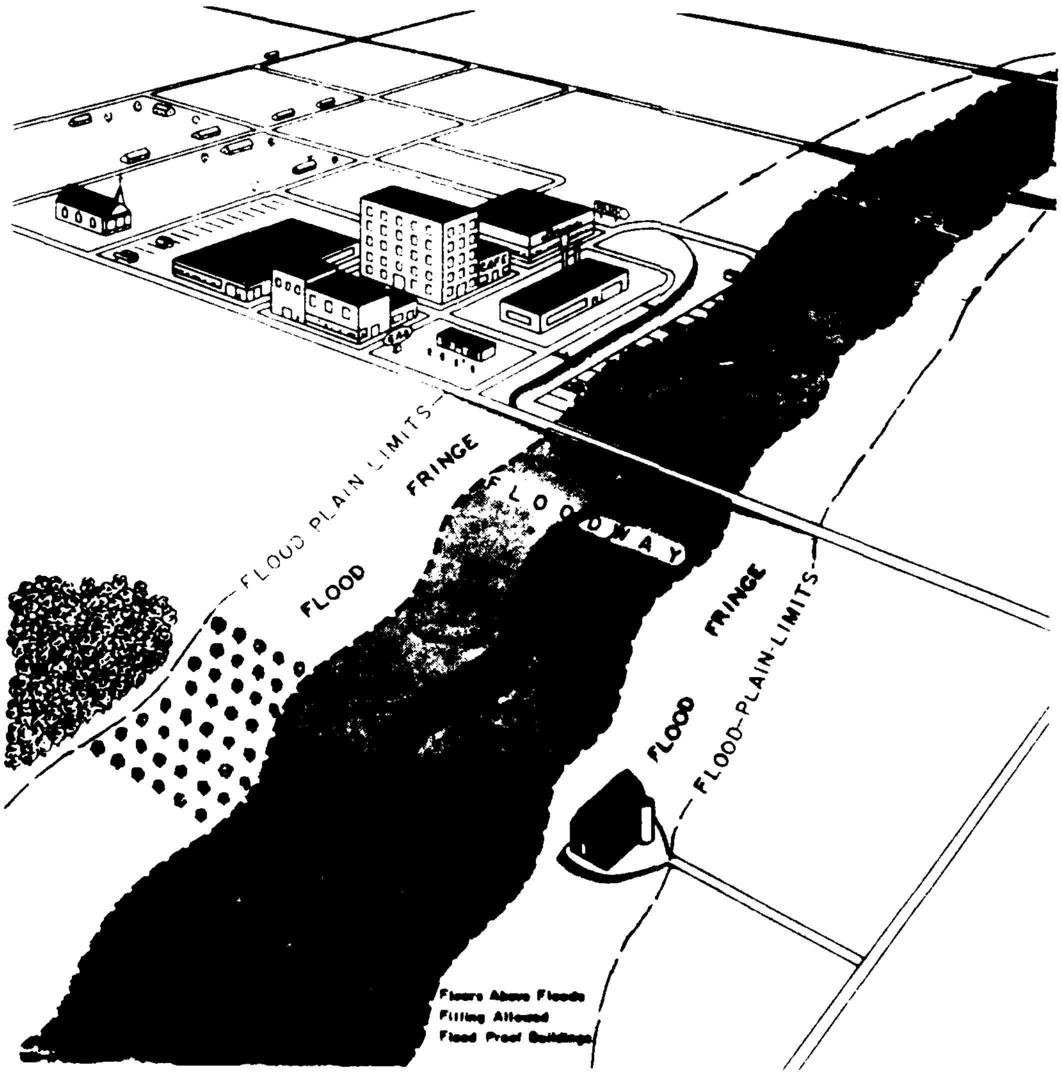
The major source of pollution in the headwaters lakes is sewage disposal into soil which is unsuitable for on-site disposal. Minnesota zoning laws now require that soil characteristics be determined before construction. With the soil location and percolation characteristics known, it would be feasible to zone the remaining undeveloped shoreland to meet specifications and thus prevent further aggravation of an already serious pollution problem.

Two Federal laws carrying substantial penalties can also assist in the control of development along the headwaters shorelands. The first is Section 10 of the 1899 River and Harbor Act which gave the Corps of Engineers authority to regulate development in navigable waters of the United States. All of the lakes included within the normal operational limits of the reservoirs formed by Corps of Engineers dams are considered navigable and are regulated under section 10. Section 10 regulates all work in waters including beach sanding projects and construction of large docks, breakwaters, small-boat channels, and harbors. Also, any work in, over, or under the headwaters lakes or any work in the immediate vicinity of the waterway affecting the course, condition, or capacity of the navigable water is subject to permit requirements under the 1899 act.

Initially, section 10 of the 1899 act was concerned only with commercial navigation, but now environmental, economic, and social issues (the overall public interest) must also be considered. Under this law, construction without a permit carries a possible fine of $2,500 per violation.

The second law, Section 404 of the Clean Water Act, gives the Corps of Engineers jurisdiction over the headwaters lakes plus the adjacent wetlands. This law gives the Corps authority over placement of fill or dredged material. Although the Corps has no direct involvement with on-land construction, nearly all construction in the reservoir area usually involves wetland fills, dredging, or beaching. Construction without a Section 404 permit, or in violation of an issued permit, is subject to a maximum fine of $25,000 per day. The Corps of Engineers must deny a permit if the Department of Natural Resources or the local government unit denies the permit first.

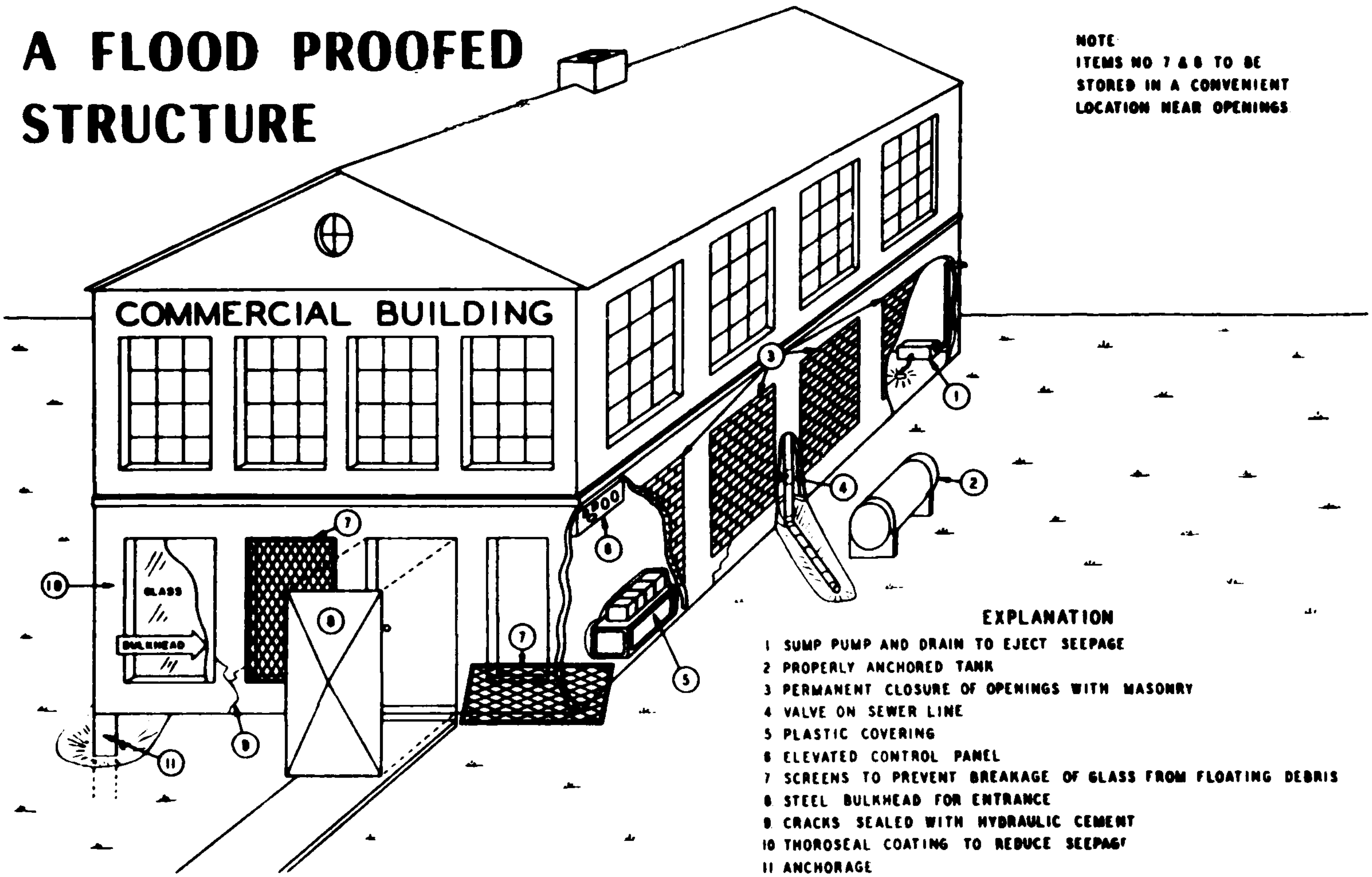
Sufficient land use laws exist to modify existing situations and control future development. Major deficiencies in current lake-shore development and land use planning are due to lack of enforcement of existing laws and accompanying benefits. What is primarily needed now is an effective means of enforcement and a coordinated means of surveillance.



FEASIBILITY REPORT
MISSISSIPPI RIVER HEADWATERS LAKES
AND AITKIN AREA STUDY - MINNESOTA
FLOOD PLAIN SCHEMATIC
St. Paul, Minnesota, District
File No. LS1-R-7/31 March 1976

PLATE C-1

A FLOOD PROOFED STRUCTURE



NOTE:
ITEMS NO 7 & 8 TO BE STORED IN A CONVENIENT LOCATION NEAR OPENINGS

EXPLANATION

1 SUMP PUMP AND DRAIN TO EJECT SEEPAGE
2 PROPERLY ANCHORED TANK
3 PERMANENT CLOSURE OF OPENINGS WITH MASONRY
4 VALVE ON SEWER LINE
5 PLASTIC COVERING
6 ELEVATED CONTROL PANEL
7 SCREENS TO PREVENT BREAKAGE OF GLASS FROM FLOATING DEBRIS
8 STEEL BULKHEAD FOR ENTRANCE
9 CRACKS SEALED WITH HYDRAULIC CEMENT
10 THOROSEAL COATING TO REDUCE SEEPAGE
11 ANCHORAGE

File No. LS1-R-7/32 March 1976

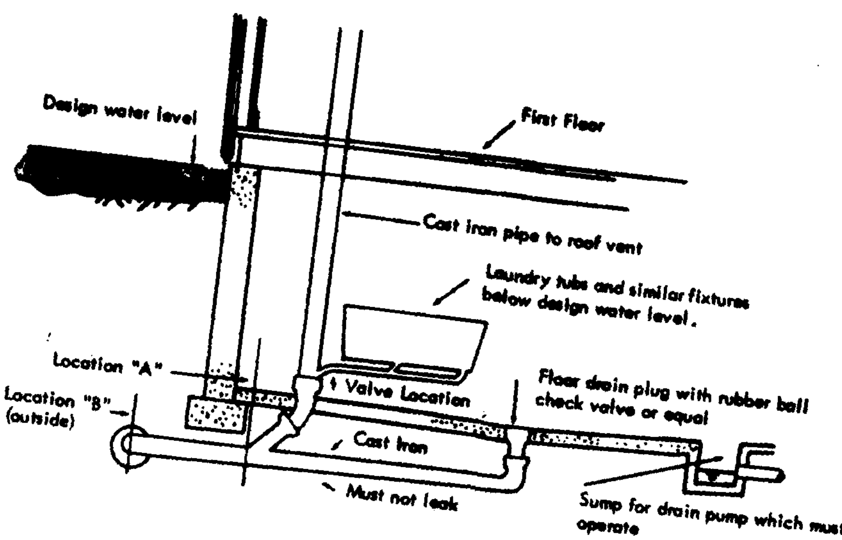


Figure E-1 - Alternative locations for cutoff valves on sewer lines.

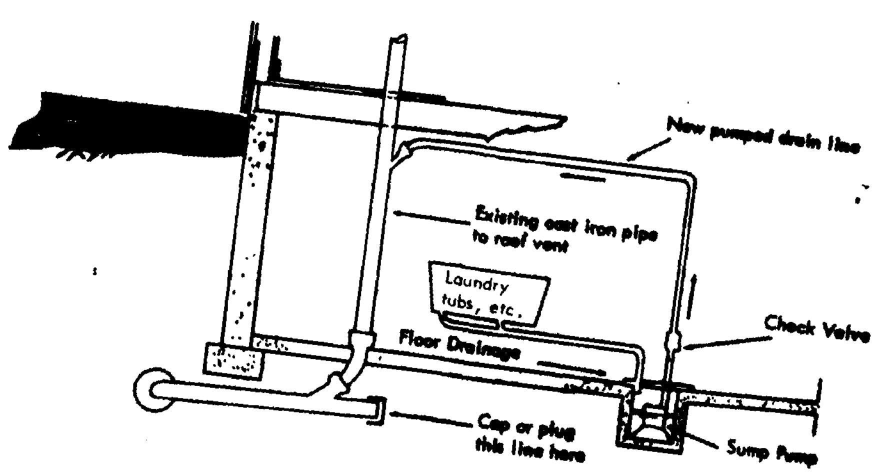


Figure E-2 - Elimination of gravity flow basement drains.

Plate C-3
Methods for controlling sewer backup

File No. LS1-R-7/33 March 1976

STAGE 3 REPORT
MISSISSIPPI RIVER HEADWATERS LAKES STUDY

WATER SUPPLY AND WATER QUALITY

A P P E N D I X D

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

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TABLES

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GENERAL

The Minnesota Pollution Control Agency has the responsibility for determining the best current uses of water at the State level and the quality of water necessary to meet these uses. The agency has further established six water use classes and has grouped the State waters into one or more of these classes. The six uses are: (1) domestic consumption, (2) fisheries and recreation, (3) industrial consumption, (4) agriculture and wildlife, (5) navigation and waste disposal, and (6) other beneficial uses. Some of the six classes are further divided into purity subclasses A, B, C, and D, with class A being the highest level of purity.

As an example, class 2A waters will permit propagation and maintenance of warmwater or cold water sport or commercial fish (including trout) and be suitable for aquatic recreation of all kinds, including bathing. Class 2B waters are suitable for warmwater or cool water sport and commercial fishing and for aquatic recreation of all kinds, including bathing. Class 2B waters are generally considered the national goal of "swimmable," "fishable" waters. Class 2C waters will permit only propagation of rough fish, or species commonly inhabiting waters of the vicinity under natural conditions, and be suitable for boating and other forms of recreation.

All segments of the Mississippi River, including the Mississippi River Headwaters Lakes, are to meet the goals of Public Law 92-500 which calls for attainment of fishable and swimmable waters by 1983.

HEADWATERS LAKES CLASSIFICATION

The six headwaters lakes are to meet the following classifications according to Minnesota Regulations WPC 24 and 25:

Lake	Interstate Class[1] (WPC-15)
Winnibigoshish	2B, 3B
Pokegama	2A, 3B

Lake	Intrastate Class[2] (WPC-14)
Leech	Not specifically listed
Sandy	Not specifically listed
Pine	Not specifically listed
Big Trout	1B, 2A, 3B
Gull	Not specifically listed

(1) Must also comply with 2C, 3C, 4A, 4B, 5, and 6.
(2) Must also comply with 2B, 2C, 3B, 3C, 4A, 4B, 5, and 6.

If the above classifications and accompanying water quality standards in WPC 14 and WPC 15 are exceeded or violated, then according to law, the water quality must be improved. All of the lakes generally comply with State and Federal standards except for the color standard on Sandy and Pine River Lakes.

WATER QUALITY STANDARDS

INTERSTATE WATERS (WPC 15)

The following information on water quality standards for interstate waters is excerpted from "Minnesota State Regulations - Rules, Regulations, Classifications, and Water Standards," Minnesota Pollution Control Agency, 1973 supplement, pages 27 through 35.

(1) Domestic Consumption

Class A The quality of this class of the interstate waters of the state shall be such that without treatment of any kind the raw waters will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards—1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to underground waters with a high degree of natural protection. The basic requirements are given below:

Substance or Characteristic	Limit or Range
Total coliform organisms	1 most probable number per 100 milliliters
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 milligram per liter
Arsenic (As)	0.01 milligrams per liter
Chlorides (Cl)	250 milligrams per liter
Copper (Cu)	1 milligram per liter
Carbon Chloroform extract	0.2 milligram per liter
Cyanides (CN)	0.01 milligram per liter
Fluorides (F)	1.5 milligrams per liter
Iron (Fe)	0.3 milligram per liter
Manganese (Mn)	0.05 milligram per liter
Nitrates (NO_3)	45 milligrams per liter
Phenol	0.001 milligram per liter
Sulfates (SO_4)	250 milligrams per liter
Total dissolved solids	500 milligrams per liter
Zinc (Zn)	5 milligrams per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Hexavalent, Cr)	0.05 milligram per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the interstate waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards—1962 for drinking water as specified in Publication No.

956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection. The physical and chemical standards quoted above for Class A [illegible] waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	10 most probable number per 100 milliliters

Class C The quality of this class of the interstate waters of the state shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards—1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where interstate water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Turbidity value	25

Class D The quality of this class of the interstate waters of the state shall be such that after treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, plus additional pre, post, or intermediate stages of treatment, or other equivalent treatment processes, the treated water will meet in all respects the recommended rquirements of the Public Health Service Drinking Water Standards—1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The concentrations or ranges given below shall not be exceeded in the raw waters before treatment:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Arsenic (As)	0.05 milligram per liter

Substance or Characteristic	Limit or Range
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Cr + 6)	0.05 milligram per liter
Cyanide (CN)	0.2 milligram per liter
Fluoride (F)	1.5 milligrams per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the interstate waters for use as a source of drinking water.

(2) Fisheries and Recreation

Class A The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and Not less than 6 milligrams per liter at other times.
Temperature	No material increase
Ammonia (N)	0.2 milligram per liter
Chlorides (Cl)	50 milligrams per liter
Chromium (Cr)	0 02 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.2 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 8.5
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bio-assays and

Substance or Characteristic	Limit or Range
	taste panels will be required to determine whether tainting is likely or present.
Turbidity value	10
Color value	30
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor exceed 400 most probable number per 100 milliliters in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of cool or warm water sport or commercial fishing and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and Not less than 5 milligrams per liter at other times.
Temperature*	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 86°F.
Ammonia (N)	1 milligram per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.02 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 9.0
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.

Substance or Characteristic	Limit or Range
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

*The following temperature criteria will be applicable for the Mississippi River from Lake Itasca to the outlet of the Metro Wastewater Treatment Works in St. Paul in addition to or superseding the above. The weekly average temperature shall not exceed the following temperatures during the specified months:

January	40°F	July	83°F
February	40°F	August	83°F
March	48°F	September	78°F
April	60°F	October	68°F
May	72°F	November	50°F
June	78°F	December	40°F

For the Mississippi River from Lock and Dam No. 2 at Hastings to the Iowa Border, the weekly average temperature shall not exceed the following temperatures during the specified months:

January	40°F	July	84°F
February	40°F	August	84°F
March	54°F	September	82°F
April	65°F	October	73°F
May	75°F	November	58°F
June	84°F	December	48°F

Class C The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of rough fish or species commonly inhabiting waters of the vicinity under natural conditions, and be suitable for boating and other forms of aquatic recreation for which the interstate waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 5 milligrams per liter from April 1 through November 30, and not less than 4 milligrams per liter at other times.
Temperature*	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature except in no case

Substance or Characteristic	Limit or Range
	shall it exceed the daily average temeprature of 90°F.
Ammonia (N)	1.5 milligrams per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.02 milligram per liter
Oil	10 milligrams per liter, and none in such quantities as to (1) produce a visible color film on the surface, (2) impart an oil odor to water or an oil taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse or taint any of the associated biota, or (4) become effective toxicants according to the criteria recommended.
pH value	6.5 - 9.0
Phenols	0.1 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a geometric mean nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of the samples.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

*The following temperature criteria will be applicable for the Mississippi River from the outlet of the Metro Wastewater Treatment Works in St. Paul to Lock and Dam No. 2 at Hastings in addition to or superseding the above. The weekly average temperature shall not exceed the following temperatures during the specified months

January	40°F	July	83°F
February	40°F	August	83°F
March	48°F	September	78°F
April	60°F	October	68°F
May	72°F	November	50°F
June	78°F	December	40°F

For all classes of fisheries and recreation waters, the aquatic habitat, which includes the interstate waters and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste or other waste effluents to the insterstate waters.

No sewage, industrial waste or other wastes shall be discharged into any of the interstate waters of this category so as to cause any material change in any other substances or characteristics which may impair the quality of the interstate waters or the aquatic biota of any of the above listed classes or in any manner render them unsuitable or objectionable for fishing, fish culture or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs.

(3) Industrial Consumption

Class A The quality of this class of the interstate waters of the state shall be such as to permit their use without chemical treatment, except softening for ground water, for most industrial purposes, except food processing and related uses, for which a high quality of water is required. The quality shall be generally comparable to Class B waters for domestic consumption, except for the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	50 milligrams per liter
Hardness	50 milligrams per liter
pH value	6.5 - 8.5
Fecal coliform organisms	200 most probable number per 100 milliliters

Class B The quality of this class of the interstate waters of the state shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment. The quality shall be generally comparable to Class D interstate waters used for domestic consumption, except the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	100 milligrams per liter
Hardness	250 milligrams per liter
pH value	6.0 - 9.0
Fecal coliform organisms	200 most probable number per 100 milliliters

Class C The quality of this class of the interstate waters of the state shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions. The following shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	250 milligrams per liter
Hardness	500 milligrams per liter

Substance or Characteristic	Limit or Range
pH value	6.0 - 9.0
Fecal coliform organisms	200 most probable number per 100 milliliters

Additional selective limits may be imposed for any specific interstate waters as needed.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for industrial purposes so as to cause any material impairment of their use as a source of industrial water supply.

(4) Agricuture and Wildlife

Class A The quality of this class of the interstate water of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops. The following concentrations or limits shall be used as a guide in determining the suitability of the waters for such uses, together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the U. S. Department of Agriculture, and any revisions, amendments or supplements thereto:

Substance or Characteristic	Limit or Range
Bicarbonates (HCO_3)	5 milliequivalents per liter
Boron (B)	0.5 milligram per liter
pH value	6.0 - 8.5
Specific conductance	1,000 micromhos per centimeter
Total dissolved salts	700 milligrams per liter
Sodium (Na)	60% of total cations as milliequivalents per liter
Fecal coliform organisms	200 most probable number per 100 milliliters
Sulfates (SO_4)	10 milligrams per liter, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the interstate waters of the state shall be such as to permit their use by livestock and wildlife without inhibition or injurious effects. The limits or concentrations of substances or characteristics given below shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
pH value	6.0 - 9.0
Total salinity	1,000 milligrams per liter
Fecal coliform organisms	200 most probable number per 100 milliliters

Substance or Characteristic	Limit or Range
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.
Unspecified toxic substances	None at levels harmful either directly or indirectly.

Additional selective limits may be imposed for any specific interstate waters as needed.

(5) **Navigation and Waste Disposal.** The quality of this class of the interstate waters of the state shall be such as to be suitable for esthetic enjoyment of scenery and to avoid any interference with navigation or damaging effects on property. The following limits or concentrations shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
pH value	6.0 - 9.0
Hydrogen sulfide	0.02 milligrams per liter

Additional selective limits may be imposed for any specific interstate water as needed.

(6) **Other Uses.** The uses to be protected in this class may be under other jurisdictions and in other areas to which the interstate waters of the state are tributary, and may include any or all of the uses listed in the foregoing categories, plus any other possible beneficial uses. The Agency therefore reserves the right to impose any standards necessary for the protection of this class, consistent with legal limitations.

June 14, 1967; Amended July 1, 1969; Amended October 13, 1971; Amended October 4, 1973.

(Due to numerous changes, only the new rule is shown here)

INTRASTATE WATERS (WPC 14)

The following information on water quality standards for intrastate waters is extracted from "Minnesota State Regulations - Rules, Regulations, Classifications, and Water Standards," Minnesota Pollution Control Agency, 1973 Supplement, pages 9 through 17.

(1) Domestic Consumption

Class A The quality of this class of the intrastate waters of the state shall be such that without treatment of any kind the raw waters will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards-1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to underground waters with a high degree of natural protection. The basic requirements are given below:

Substance or Characteristic	Limit or Range
Total coliform organisms	1 most probable number per 100 milliliters
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 milligram per liter
Arsenic (As)	0.01 milligram per liter
Chlorides (Cl)	250 milligrams per liter
Copper (Cu)	1 milligram per liter
Carbon Chloroform extract	0.2 milligram per liter
Cyanides (CN)	0.01 milligram per liter
Fluorides (F)	1.5 milligrams per liter
Iron (Fe)	0.3 milligram per liter
Manganese (Mn)	0.05 milligram per liter
Nitrates (NO_3)	45 milligrams per liter

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Substance or Characteristic	Limit or Range
Phenol	0.001 milligram per liter
Sulfates (SO_4)	250 milligrams per liter
Total dissolved solids	500 milligrams per liter
Zinc (Zn)	5 milligrams per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Hexavalent, Cr)	0.05 milligram per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the intrastate waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards-1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection. The physical and chemical standards quoted above for Class A intrastate waters shall also apply to these intrastate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	10 most probable number per 100 milliliters

Class C The quality of this class of the intrastate waters of the state shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards-1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where intrastate water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The physical and chemical standards quoted above for Class A intrastate waters shall also apply to these intrastate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Turbidity value	25

Class D The quality of this class of the intrastate waters of the state shall be such that after treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, plus additional pre, post, or intermediate stages of treatment, or other equivalent treatment processes, the treated water will meet in all respects the recommended requirements of the Public Health Service Drinking Water Standards-1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The concentrations or ranges given below shall not be exceeded in the raw waters before treatment:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
Arsenic(As)	0.05 milligram per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Cr + 6)	0.05 milligram per liter
Cyanide (CN)	0.2 milligram per liter
Fluoride (F)	1.5 milligrams per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive Material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any intrastate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the instrastate waters for use as a source of drinking water.

(2) Fisheries and Recreation

Class A The quality of this class of the intrastate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting

concentrations or ranges of substances or characteristics which should not be exceeded in the intrastate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and Not less than 6 milligrams per liter at other times
Temperature	No material increase
Ammonia (N)	0.2 milligram per liter
Chlorides (Cl)	50 milligrams per liter
Chromium (Cr)	0.02 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.02 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 8.5
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bio-assays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	10
Color value	30
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor exceed 400 most probable number per 100 milliliters in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the intrastate waters of the state shall be such as to permit the propagation and maintenance of cool or warm water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the intrastate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and

Substance or Characteristic	Limit or Range
	Not less than 5 milligrams per liter at other times.
Temperature	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 86 F.
Ammonia (N)	1 milligram per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value.
Cyanides (CN)	0.02 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 9.0
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other freshwater edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class C The quality of this class of the intrastate waters of the state shall be such as to permit the propagation and maintenance of rough fish or species commonly inhabiting waters of the vicinity under natural conditions, and be suitable for boating and other forms of aquatic recreation for which the interstate waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the intrastate waters are given below:

Substance or Characteristic	Limits or Range
Dissolved oxygen	Not less than 5 milligrams per liter from April 1 through November 30, and not less than 4 milligrams per liter at other times.

Substance or Characteristic	Limit or Range
Temperature	5° above natural in streams and 3° above natural in lakes, based on monthly average of the maximum daily temperature except in no case shall it exceed the daily average temperature of 90° F.
Ammonia (N)	1.5 milligrams per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value
Cyanides (CN)	0.02 milligram per liter
Oil	10 milligrams per liter, and none in such quantities as to (1) produce a visible color film on the surface, (2) impart an oil odor to water or an oil taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse or taint any of the associated biota, or (4) become effective toxicants according to the criteria recommended.
pH value	6.5-9.0
Phenols	0.1 milligram per liter and none that could impart odor or taste to fish flesh or other freshwater edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a geometric mean nor equal or exceed 2000 most probable number per 100 milliliters in more than 10% of the samples.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use

For all classes of fisheries and recreation waters, the aquatic habitat, which includes the intrastate waters and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota nor-

mally present shall not be prevented or hindered by the discharge of any sewage, industrial waste or other waste effluents to the intrastate waters.

No sewage, industrial waste or other wastes shall be discharged into any of the intrastate waters of this category so as to cause any material change in any other substances or characteristics which may impair the quality of the intrastate waters or the aquatic biota of any of the above-listed classes or in any manner render them unsuitable or objectionable for fishing, fish culture or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs.

(3) Industrial Consumption

Class A The quality of this class of the intrastate waters of the state shall be such as to permit their use without chemical treatment, except softening for ground water, for most industrial purposes, except food processing and related uses, for which a high quality of water is required. The quality shall be generally comparable to Class B waters for domestic consumption, except for the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	50 milligrams per liter
Hardness	50 milligrams per liter
pH value	6.5-8.5
Fecal coliform organisms	200 most probable number per 100 milliliters

Class B The quality of this class of the intrastate waters of the state shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment. The quality shall be generally comparable to Class D intrastate waters used for domestic consumption, except the following:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	100 milligrams per liter
Hardness	250 milligrams per liter
pH value	6.0-9.0
Fecal coliform organisms	200 most probable number per 100 milliliters

Class C The quality of this class of the intrastate waters of the state shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions. The following shall not be exceeded in the intrastate waters:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	250 milligrams per liter
Hardness	500 milligrams per liter
pH value	6.0-9.0
Fecal coliform organisms	200 most probable number per 100 milliliters

Additional selective limits may be imposed for any specific intrastate waters as needed.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by

any person to gain access to any intrastate waters classified for industrial purposes so as to cause any material impairment of their use as a source of industrial water supply.

(4) Agriculture and Wildlife

Class A The quality of this class of the intrastate waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops. The following concentrations or limits shall be used as a guide in determining the suitability of the waters for such uses, together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the U. S. Department of Agriculture, and any revisions, amendments or supplements thereto:

Substance or Characteristic	**Limit or Range**
Bicarbonates (HCO_3)	5 milliequivalents per liter
Boron (B)	0.5 milligram per liter
pH value	6.0-8.5
Specific conductance	1,000 micromhos per centimeter
Total dissolved salts	700 milligrams per liter
Sodium (Na)	60% of total cations as milliequivalents per liter
Fecal coliform organisms	200 most probable number per 100 milliliters
Sulfates (SO_4)	10 milligrams per liter, applicable to waters used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class B The quality of this class of the intrastate waters of the state shall be such as to permit their use by livestock and wildlife without inhibition or injurious effects. The limits or concentrations of substances or characteristics given below shall not be exceeded in the intrastate waters:

Substance or Characteristic	***Limit or Range***
pH value	6.0-9.0
Total salinity	1,000 milligrams per liter
Fecal coliform organisms	200 most probable number per 100 milliliters
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.
Unspecified toxic substances	None at levels harmful either directly or indirectly.

Additional selective limits may be imposed for any specific intrastate waters as needed.

(5) **Navigation and Waste Disposal.** The quality of this class of the intrastate waters of the state shall be such as to be suitable for esthetic enjoyment of scenery and to avoid any interference with navigation or damaging effects on property. The following limits or concentrations shall not be exceeded in the intrastate waters:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number per 100 milliliters
pH value	6.0-9.0
Hydrogen sulfide	0.02 milligrams per liter

Additional selective limits may be imposed for any specific intrastate waters as needed.

(6) **Other Uses.** The uses to be protected in this class may be under other jurisdictions and in other areas to which the intrastate waters of the state are tributary, and may include any or all of the uses listed in the foregoing categories, plus any other possible beneficial uses. The Agency therefore reserves the right to impose any standards necessary for the protection of this class, consistent with legal limitations.

Filed August 15, 1967. Amended October 4, 1973.

(Due to numerous changes, only the new rule is shown here)

WATER QUALITY SUMMARY

The quality of water from the Mississippi River Headwaters Lakes is of concern to both lake residents and downstream interests. Water samples taken in 1972 and 1973 from each of the six headwaters lakes indicated that the water was of acceptable quality for use as a public water supply in all but Sandy Lake, where water was too high in iron and color to warrant general use without treatment.

The water from these lakes also met normal bacteriological expectations in 1973. Bacteriological plate counts were less than 20,000 mg/l (milligrams per liter), and coliform organisms were far less than the 50-mg/l standard which defines water suitable for recreation activities involving total body immersion. The following two tables summarize the headwaters lakes 1973 water quality conditions with various standards of comparison.

Water quality of lake samples compared with various standards

Parameter	Units[3]	Standards[1] WPC 14 (2B,3B,4A)	WCP 15 (2A,2B,3B)	EPA Domestic use	EPA Fish and wildlife	EPA Agri-culture	Observed average measurement[2] in lakes Winnibi-goshish	Leech	Pokeg-ama	Sandy	Pine River	Gull
pH		6.5-9.0	6.5-8.5	5.0-9.0	6.5-9.0	-	7.8	7.6	7.6	7.2	7.8	7.6
Dissolved oxygen	mg/l(min)	5.0	5.0	-	5.0		(7)	(5)	(6)	(6)	(6)	(5)
Turbidity	Jackson unit(max)	25.0	10.0	-	-	-	3	2	2	4	1	2
Alkalinity	mg/l($CaCO_3$)	-	-	400(max)	20(min)		143	143	144	46	122	104
Nitrate-nitrite N	mg/l(max)	-	-	10.0	-	-	0.1	0.1	0.1	0.1	0.1	0.1
Ammonia N	mg/l(max)	1.0	0.2	-	0.02	-	0.05	0.02	0.04	0.04	0.03	0.03
Dissolved solids	mg/l(max)	-	-	-	-	-	159	163	168	110	124	126
Color[4]	Units(max)	30.0	30.0	75.0	-	-	-	-	-	(100)	(37)	(20)
Sulfate	mg/l(max)	10.0	-	-	-	-	-	-	2	-	9	-
Chromium	ug/l(max)	5.0	20.0	50.0	100	-	<20	<20	<20	<20	<20	<20
Copper	ug/l(max)	10.0	10.0	1,000	-	-	9	8	14	11	11	10
Iron	ug/l(max)	-	-	300	1,000	-	250	200	210	650	200	170
Arsenic	ug/l(max)	-	-	50	-	100	50	30	40	60	30	30

(1) Water Pollution Control (WPC) Standards of the State of Minnesota and the U.S. Environmental Protection Agency (Quality Criteria for Water, July 1976).

(2) Sample data from 1973 Environmental Review Report by Bemidji State University. Concentrations given in parentheses are derived from prior publications.

(3) mg/l = milligrams per liter. ug/l = micrograms per liter.

(4) Platinum - cobalt scale units.

Microbial composition of water samples (July 1973)

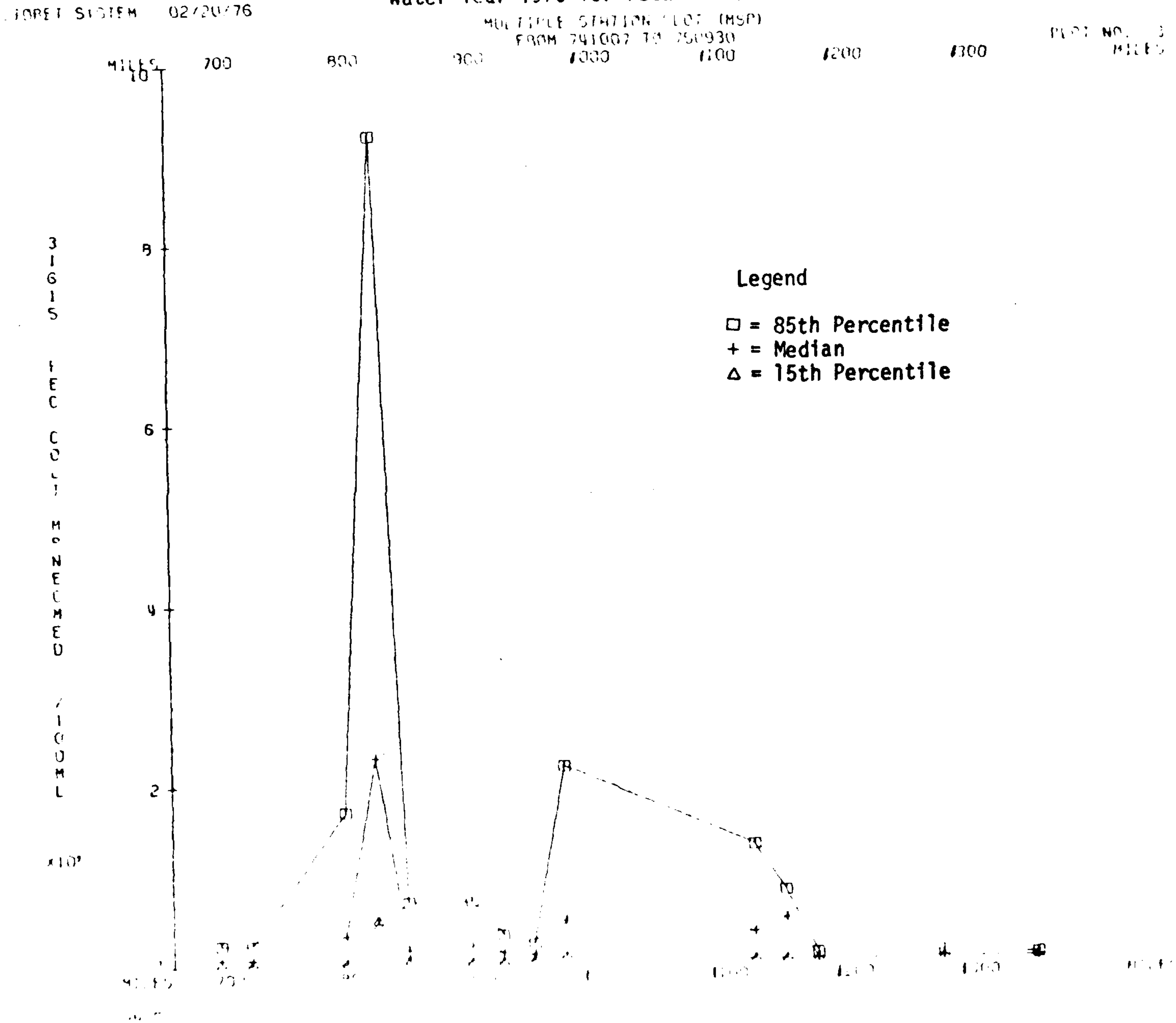
Sample site	Microorganisms per 100 milliliters Total	Coliform	Fecal coliform
Winnibigoshish Lake			
Reservoir	168	1	0
Below dam	4,368	0	0
Leech Lake			
Reservoir	4,956	0	0
Below dam	5,292	0	0
Pokegama Lake			
Reservoir	1,596	0	0
Below dam	3,360	0	0
Sandy Lake			
Reservoir	5,544	0	0
Below dam	3,780	0	0
Pine River Lake			
Reservoir	3,276	1	0
Below dam	2,688	1	0
Gull Lake			
Reservoir	1,764	0	0
Below dam	6,552	0	0
Mississippi River above Brainerd	1,764	0	0

Total plate counts of less than 20,000 organisms per 100 milliliters are considered acceptable for activities involving total body immersion, such as swimming. Waters having 0 to 50 total coliform organisms per 100 milliliters meet U.S. Public Health Service Standards for use as a water supply with simple chlorination. Waters classified for recreation of all kinds should not exceed 200 most probable number per 100 milliliters (MPN per 100 ml) fecal coliform and water suitable for domestic consumption should not exceed 10 MPN per 100 ml fecal coliform according to Minnesota standards.

Effluent from the Bemidji, Minnesota, waste treatment plant was a major concern during the period 1976-77. The city is attempting to upgrade the effluent quality of the system under guidance from the Minnesota Pollution Control Agency. The effluent is discharged into the Mississippi River upstream of the six headwaters lakes.

Currently, 141 municipalities and 96 industrial facilities discharge into surface waters in the basin above St. Paul, Minnesota. The nine monitoring sites maintained by the Minnesota Pollution Control Agency on the Upper Mississippi River main stem portion of the basin show the major water quality problem to be fecal coliform levels. The limiting water quality parameter for fecal coliform levels is 200 MPN (most probable number) per 100 milliliters, and the limiting parameter is exceeded 33 percent of the time. The major sources of the problem are concentrated urb in areas such as Bemidji, Grand Rapids, and Brainerd, Minnesota. A plot profile of water year 1975 fecal coliform levels for the Mississippi River to the Iowa border was developed by the Minnesota Pollution Control Agency and is shown on the following profile.

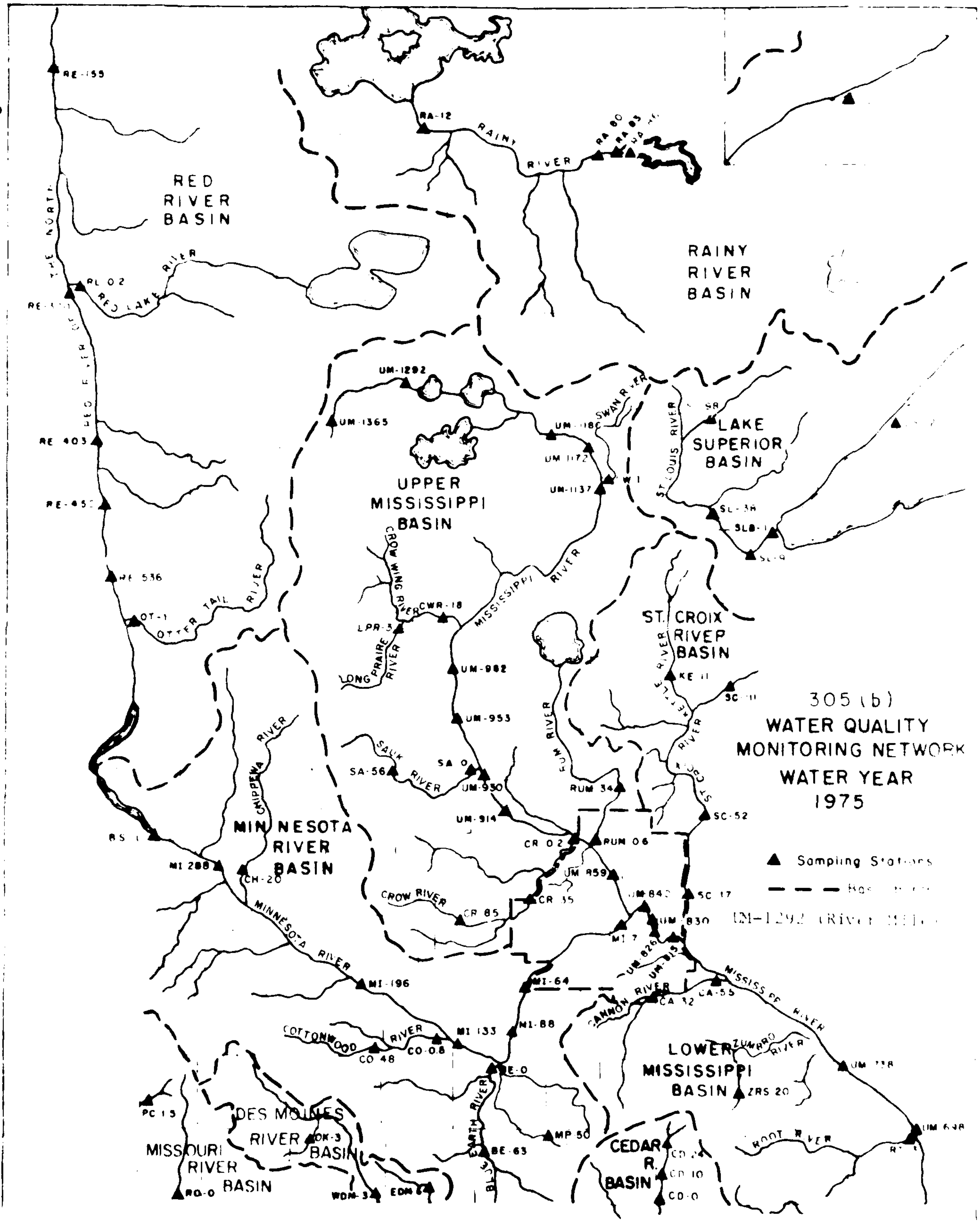
FIGURE II-5C Mi ssippi River
Water Year 1975 for Fecal Coliform



The following locations of significant municipalities, tributaries, and geographic features of the Mississippi River aid in evaluating the preceding concentration versus river mile plots.

River mile	Municipality or tributary
1365	Lake Itasca
1292	Bemidji
1186	Cohasset
1177	Grand Rapids
1010	Brainerd
929	St. Cloud
854	St. Anthony Falls
844	Minnesota River
835	Metropolitan Wastewater Treatment plant
813	Vermillion River
811	St. Croix River
797	Red Wing
728	Winona
674	Iowa border

Data for the fecal coliform profile plot and for other water quality parameters were obtained from a primary monitoring network operated by the Minnesota Pollution Control Agency. The location of the primary network stations is shown on the following location map.


RED RIVER BASIN
RAINY RIVER BASIN
UPPER MISSISSIPPI BASIN
LAKE SUPERIOR BASIN
ST. CROIX RIVER BASIN
MINNESOTA RIVER BASIN
LOWER MISSISSIPPI BASIN
CEDAR R. BASIN
DES MOINES RIVER BASIN
MISSOURI RIVER BASIN
RAINY RIVER
RED LAKE RIVER
OTTER TAIL RIVER
CROW WING RIVER
LONG PRAIRIE RIVER
MISSISSIPPI RIVER
SAUK RIVER
CROW RIVER
CHIPPEWA RIVER
MINNESOTA RIVER
COTTONWOOD RIVER
BLUE EARTH RIVER
CANNON RIVER
ZUMBRO RIVER
ROOT RIVER
RUM RIVER
SWAN RIVER
ST. LOUIS RIVER
ST. CROIX RIVER
KETTLE RIVER
RE-155
RA-12
RA 60
PL 02
RE 403
RE-452
RE 536
OT-1
UM-1292
UM-1365
UM-1172
UM-1137
SL-38
SLB-1
CWR-18
LPR-3
UM-982
UM-953
KE 11
SC-52
SA-56
SA 0
UM-930
UM-914
RUM 34
CR 02
RUM 06
UM 859
UM 840
SC 17
UM 830
CR 35
CR 85
BS-1
MI 288
CH-20
MI 7
MI-196
MI-64
CA 32
CA-55
MI-88
MI 133
CO 48
CO-0.8
BE-0
UM 738
ZRS 20
PC 15
DK-3
MP 50
BE-63
CD 24
CD 10
CD-0
RO-0
WDM-3
EDM 64
305 (b)
WATER QUALITY
MONITORING NETWORK
WATER YEAR
1975
Sampling Stations

WATER QUALITY BY LANDSAT

MINNESOTA POLLUTION CONTROL AGENCY

The Minnesota Pollution Control Agency completed a land satellite imagery study of much of the Mississippi River Headwaters Area in November 1977, in cooperation with the University of Wisconsin and Bendix Aerospace Systems. The study produced colored images showing specific land uses and water quality parameters on 1:250,000 scale maps. A copy of the September 1976 Land Satellite Scene and legend is shown on the following pages.

See page 61 of the main report.

Land Satellite Scene, September 1976

Land Satellite legend

Color	Identification
Color code - water	
Dark blue	Deep, clear water (oligotrophic lakes).
Turquoise	Marl lakes (calcium carbonate particles suspended in water) or other clear water with small amounts of glacial flour, rock flour, or soil particles in it (oligotrophic lakes).
Light green	Non-tannin water with light to medium algae.
Dark green	Medium to heavy algae (eutrophic lakes).
Brown	Brown tannin water or heavy silt/mud suspended in water, sand/mud bottom showing, or light to medium wild rice or other water grasses in shallow water.
White	In lakes: heavy wild rice or other water grasses obscuring the water.
Black	Unclassified.
Color code - land	
Pink	Bare rock or bare concrete.
White	Open disturbed areas (i.e., cities, old mines, etc.) or marsh grass over wetland.
Yellow	Predominantly nonforest open, small thin conifers, or brush.
Light gray	Hardwoods and hardwood/conifer mix.
Dark gray	Conifers.
Black	Unclassified.

The Land Satellite survey and related ground checking is a convenient way to cover a large area and obtain general information on lake water quality at a cost of \$2 to \$4 per square mile. This type of survey can be used to locate problem areas which can then be analyzed closer with standard water sampling techniques. However, the Land Satellite imagery must be correlated closely with ground observations to distinguish whether a lake such as Pokegama, for example, has a suspended silt problem, is high in tannin, or is covered with wild rice.

The Land Satellite scene for the Mississippi River Headwaters area appears to indicate the characteristics shown in the following table.

Land Satellite identification - Mississippi River Headwaters area

Lake	Color	Identification
Winnibigoshish	Dark blue with brown bonding	Deep lake with lake bottom or suspended silt showing.
Leech	Turquoise to dark blue	Generally a marl lake with several wild rice bays.
Pokegama	Brown	Lake bottom, suspended silt, or tannin showing.
Sandy	Green and brown	Light algae and wild rice.
Pine River (Whitefish chain)	Blue-brown and green	Clear areas, silt or tannin areas, algae areas.
Gull	Not shown	

REGION 5 REGIONAL DEVELOPMENT COMMISSION

The Region 5 Regional Development Commission in Staples, Minnesota, completed a water quality study in the Mississippi River Headwaters study area in 1977, using land satellite imagery. The study included that portion of the Mississippi River Headwaters Lakes area in Cass and Crow Wing Counties.

The study attempted to identify a number of water quality parameters for the water areas but was successful only in correlating secchi depth and chlorophyll a. Secchi depth is a measurement of the transparency of water; the lower the secchi measurement, the more suspended matter is present. Chlorophyll a is used to estimate the nutrient load and resultant eutrophication of a lake. Excessive chlorophyll a levels and resultant eutrophication limit the usefulness of water bodies for recreation, water supply, and other purposes.

The Region 5 Regional Development Commission study shows that the six headwaters lakes have no unusual problems with water clarity or algal growth except for Leech Lake and Pokegama flowage lakes. The east and west bays of Leech Lake and several upstream flowages into Pokegama Lake show high chlorophyll a (nutrients).

Four Land Satellite scenes and a legend are shown on the following table and photographs.

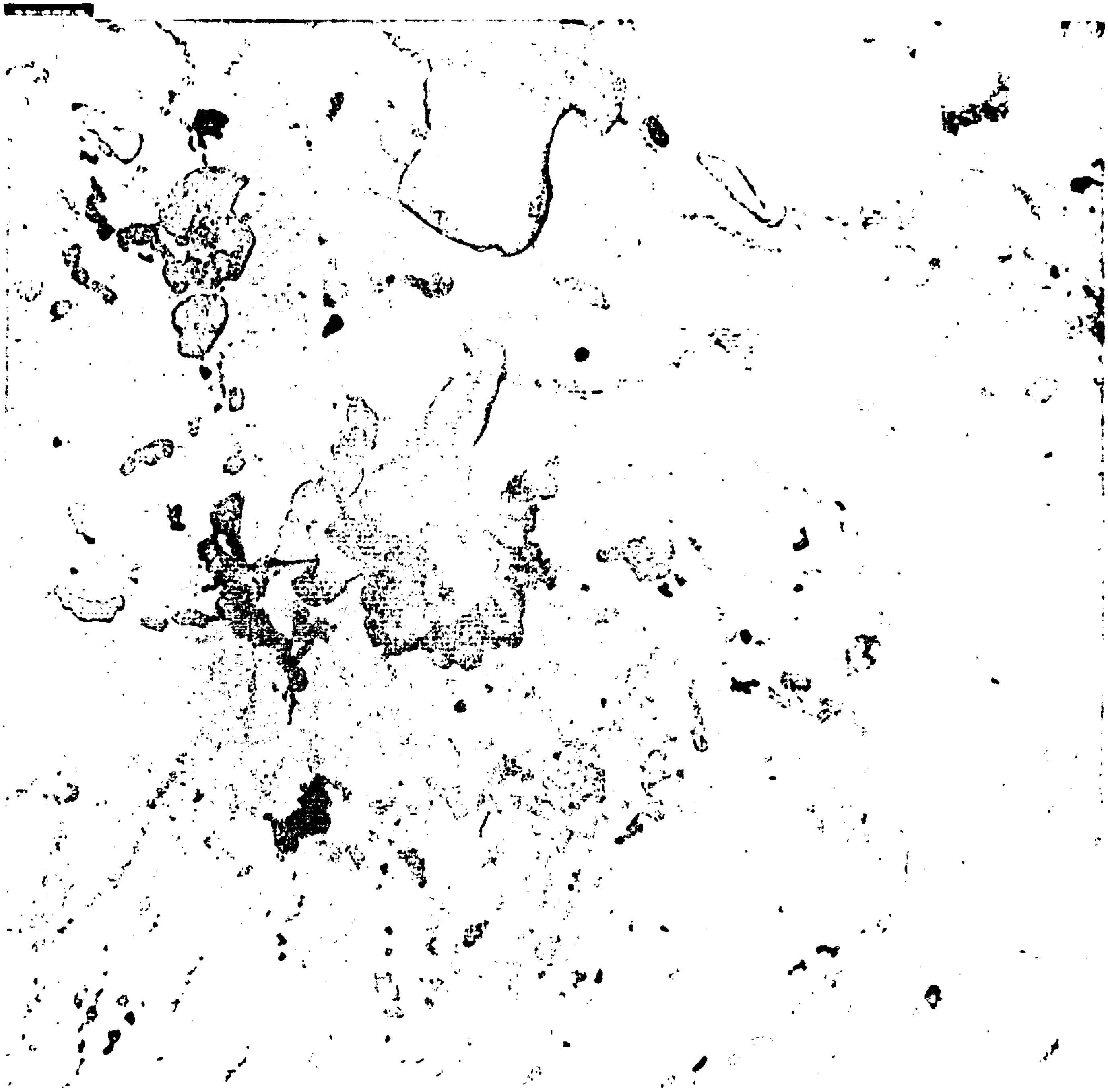
[illegible]and Sat[illegible] [illegible] legend, parameter - [illegible] [illegible]ion	
Parameter	[illegible]

S[illegible] [illegible] (feet)

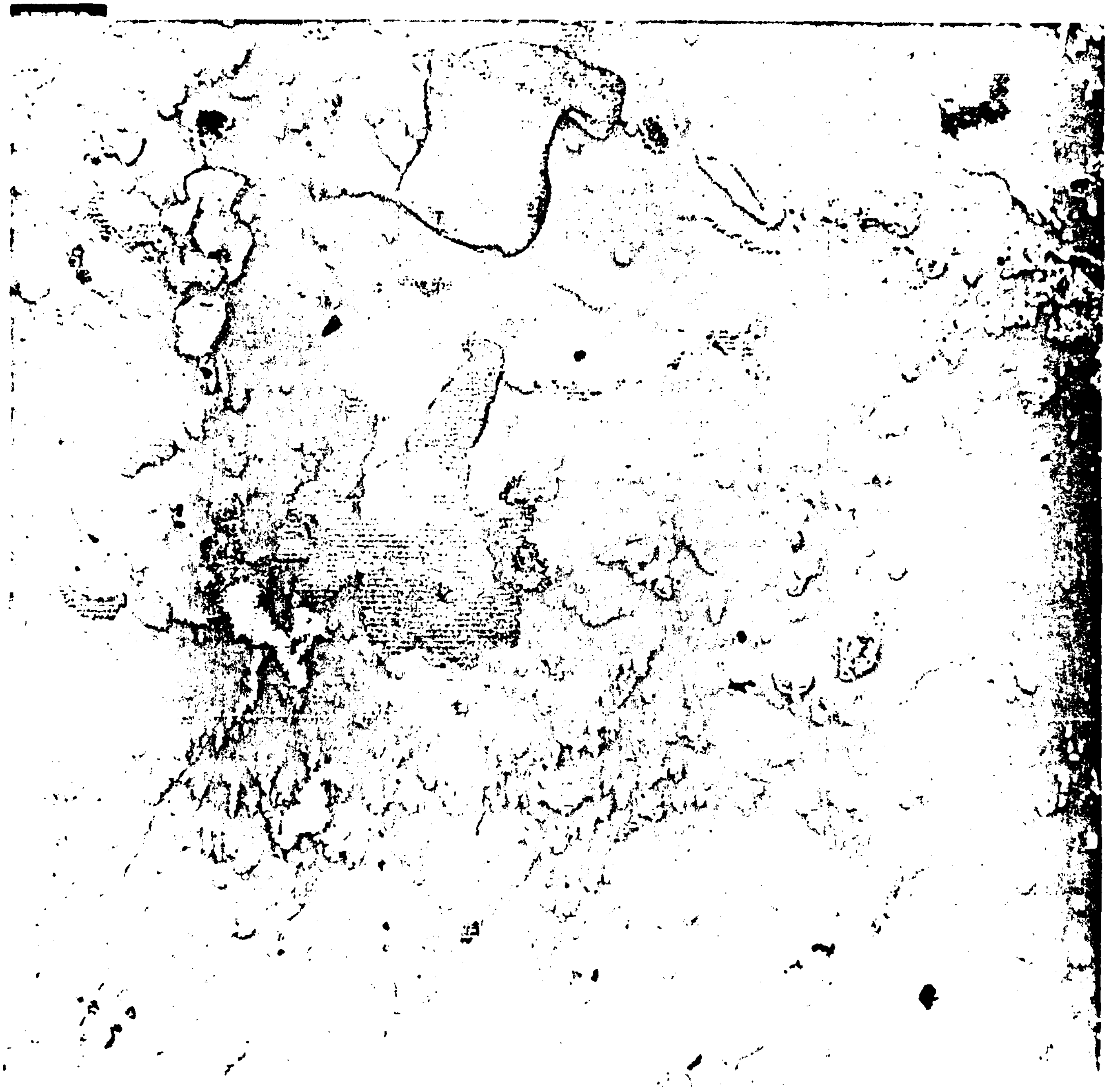
0 - 2.49	Dark magenta
2.5 - 4.9	Blue
5.0 - 7.49	Cyan
7.[illegible] - 9.9	Gr[illegible]
10.0 - 12.49	Or[illegible]
12.[illegible] - 14.99	[illegible]
15+	Brown

Chl[illegible]ph[illegible]ll a concentration (Ug/l)

0 - 11.49	Magenta
11.5 - 24.99	Dark magenta
25 - 49	Blue
50 - 99.9	[illegible]
100 - [illegible]	Gre[illegible]
1[illegible] - 1[illegible]	Yellow
200 - [illegible]9.9	Red
[illegible]	Brown



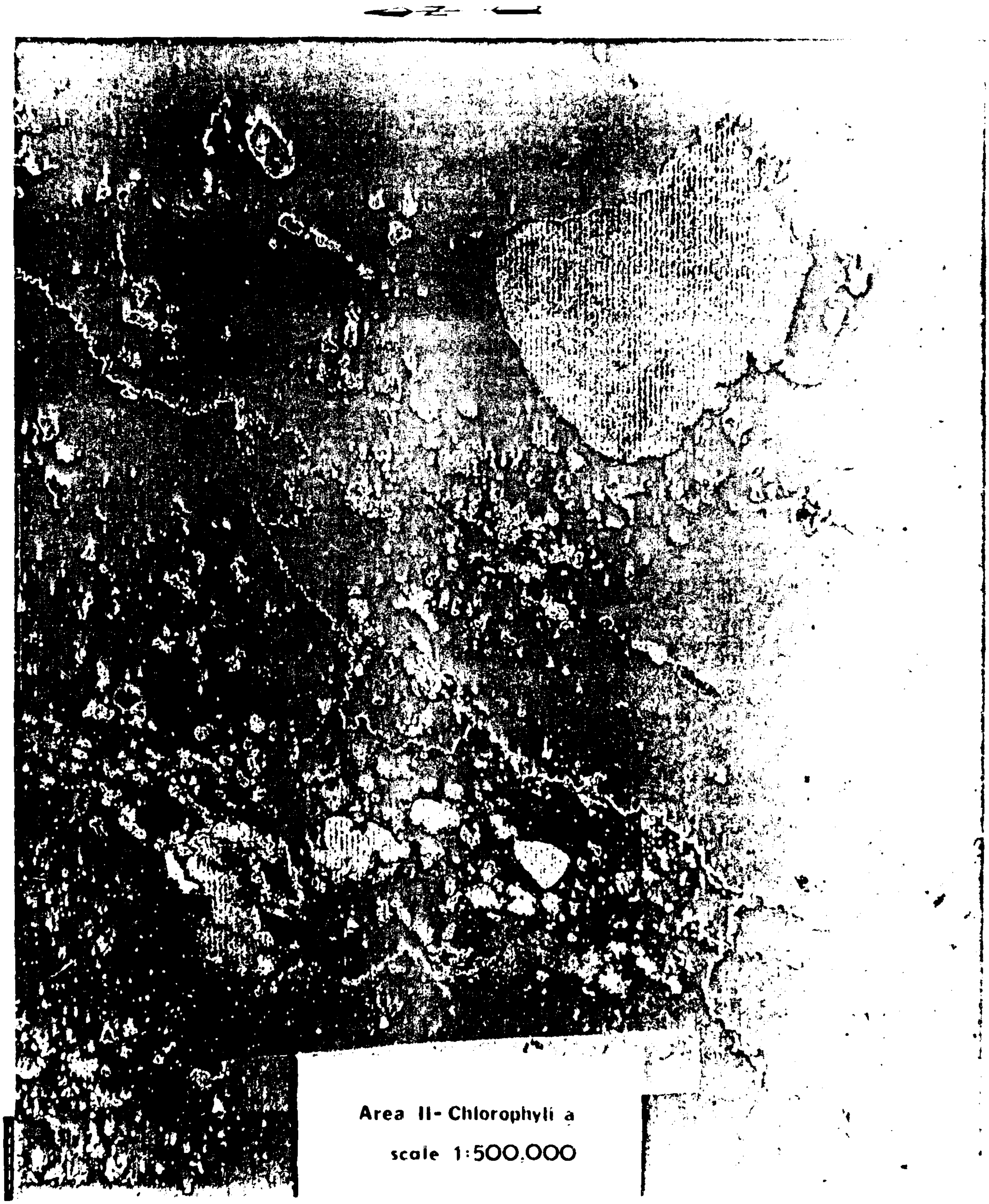
Area I - Secchi
scale 1 : 500.000



Area I - Chlorophyll a
scale 1 500 000

Area II - Secchi

scale 1 : 500,000



Area II- Chlorophyll a

scale 1:500,000

LIMNOLOGICAL SURVEY

All six headwaters lakes were surveyed in a 1-year water quality sampling program from August 1978 to September 1979 by the St. Paul District, Corps of Engineers. The work was part of a District program to obtain basic data on 16 impoundments operated by the Corps. The data will be used to determine the need for future water quality sampling, identify potential and existing water problems, and help determine the need for revising present lake operations to improve water quality.

The 16-reservoir survey was conducted by the University of Minnesota under contract to the Corps. A summary of the survey results was published in a four-part report prepared by the University of Minnesota's Department of Ecology and Behavioral Biology in May 1980.

The results of the 1979-1980 survey illustrate that the Mississippi River Headwaters Lakes have significantly better water quality than lakes [illegible] portions of the St. Paul District. The headwaters lakes have [illegible] lower concentrations of chlorophyll a, are more transparent, and are [illegible] [illegible].

Mean concentrations of chlorophyll a indicate that [illegible] more abundant in Lac qui Parle and Lake [illegible], [illegible], than in Pokegama Lake and Cross Lake, located in [illegible] central Minnesota. Mean concentrations of chlorophyll in the reservoirs depend on concentrations of phosphorus; there are strong linear correlations between mean chlorophyll and mean total phosphorus and between mean chlorophyll and mean particulate phosphorus. Mean concentrations of particulate organic materials (PCOD) in the reservoirs are also strongly correlated with mean concentrations of phosphorus.

Samples were collected from most of the reservoirs, usually at three or more sites, on six dates during spring, summer, and autumn. Mean concentrations of chlorophyll a, PCOD, phosphorus, and specific conductance in surface samples were computed from means for each sampling date. (See the following table.)

Summary table - 1979-80 limnological survey[1]

Reservoir		Chl	PCOD	TP	PP	CON
1.	Pokegama	5.5	45	1.1	0.5	238
2.	Cross	6.0	50	1.1	0.8	218
3.	Leech	7.0	69	1.3	0.4	249
4.	Gull	9.8	66	1.3	0.5	204
5.	Winnibigoshish	13	87	1.9	0.5	253
6.	Red	14	259	1.7	0.9	243
7.	Big Sandy	16	92	1.9	1.6	102
8.	Homme	22	84	3.9	1.3	563
9.	Orwell	26	104	3.6	1.5	363
10.	Ashtabula	30	159	6.1	1.8	521
11.	Eau Galle	42	109	2.4	1.4	241
12.	Mud	47	180	8.0	3.6	[illegible]
13.	Highway 75	63	186	8.2	2.8	[illegible]
14.	Marsh	69	323	6.6	3.9	775
15.	Lac Qui Parle	77	213	6.5	3.3	[illegible]
16.	Traverse	81	258	8.8	4.1	[illegible]

(1) The table shows mean concentrations of chlorophyll *a* (mg Chl m^{-3}), particulate chemical oxygen demand (mmole PCOD m^{-3}), total phosphorus (TP, mmole m^{-3}), particulate phosphorus (PP, mmole m^{-3}), and mean conductance (CON, μmho cm^{-1}) in water during spring, summer, and autumn. The reservoirs are ranked in order of increasing concentrations of chlorophyll *a*.

ACID [illegible]

The following information on acid rain [illegible] from a June 198[illegible] report by the Minnesota Pollution Control Agency ([illegible]) titled "Acid Precipitation Impact Assessment in Minnesota Derived from Current and Historical Data." The MPCA report compares summer and fall 1980 sampling efforts with historical data dating back to 1936.

The MPCA report indicates that there is [illegible] documentation of lake acidification as a result of acid rain in Min[illegible] at this time. However, the northeastern part of Minnesota is [illegible] susceptible to acidification because of the natural geology.

Lakes with low alkalinity occur in [illegible] because of the natural geology of the area. Lakes with a pH value of less than [illegible] are [illegible] acidic. Lakes with a low alkalinity of say 0 to 45, like those of the Boundary Waters Canoe Area in northern Minnesota, are highly susceptible [illegible] the effects of acid rain. The Boundary Waters Canoe Area is under[illegible] [illegible] by noncalcareous soils.

[illegible] is [illegible] of a problem for [illegible] lakes with [illegible] drainage [illegible] [illegible] sampled in the MPCA [illegible] [illegible] naturally ac[illegible] [illegible] pH [illegible]

The six headwaters lakes, in contrast, generally have high alkalinity and a large buffering capacity. However, [illegible] observed alkalinity of [illegible] Sandy Lake (from data recorded by Bemidji State University in 19[illegible]) [illegible] to place that lake in the low alkalinity range. Sandy Lake's [illegible] alkalinity apparently stems from its natural bo[illegible] system.

In any event, the MPCA study shows that there is a trend towards [illegible] alkalinity in central and northeastern Minnesota, including [illegible] containing the six headwaters lakes. Trends revealed [illegible] the MPCA study by county and affected lakes are as follows:

Changes in alkalinity

County	Lake	Percent of lakes showing decline in alkalinity	Mean change in alkalinity
Itasca	Winnibigoshish Pokegama	86	+12.9
Cass	Winnibigoshish Leech Gull	80	-4.0
Aitkin	Sandy	No 1980 test data	-
Crow Wing	Pine Gull	100	-8.0

Based on the MPCA report, we conclude that although there is a trend toward acidification of smaller lakes with limited drainage areas, five of the six headwaters lakes are not likely to be adversely affected by acid rain. Their relatively large sizes and drainage areas and their watershed geology tend to offset the effects of acid rain.

Sandy Lake could be the exception in that the till plain soil of Aitkin County is slightly acidic and the lake has the bog system that contributes to dissolved organic material and humic acids. The water of Sandy Lake also has coloration related to bog stain. However, offsetting the trend to acidity is Sandy Lake's relatively large drainage area-to-lake area ratio which contributes to a large flushing capability. The Sandy Lake flowage, with 421 square miles of drainage area and about 16.5 square miles of pool area, has the largest drainage area-pool area ratio of the six headwaters lakes. In any event, Sandy Lake bears watching for future adverse effects of acid rain.

WATER QUAL[illegible]

Water quality references used for this re[illegible]t include the following:

"Environmental Review of the Headwaters of the Mississippi Reserv[illegible]ir Projects," The Center for Environmental Studies of Bemidji State University, 1973.

Me[illegible]ard, Robert O., University of Minnesota, "Limnological Survey of [illegible]eservoirs in Minnesota, North Dakota, and Wis[illegible]sin, operated by the Corps [illegible] Engineers" (Parts I, II, III, IV), May 19[illegible].

Minne[illegible]ta Pollution Control A[illegible]ency, "A[illegible] [illegible]ecipitation [illegible] [illegible] in Minnesota Derived From [illegible] [illegible]orical data," [illegible]

Minnesota Pollution Control Agency, "1976 Minnesota Water Quality [illegible]ent[illegible]ry - Report to Congress - Section 305 (b)," April 1976.

Minnes[illegible] [illegible]ution Control Agency, "Landsat Multispect[illegible] [illegible] [illegible]thern Minne[illegible]," October 1977.

[illegible] [illegible]lution Control Agency, "Rep[illegible] [illegible] inv[illegible] [illegible] [illegible] Gull Lake Chain, Cass [illegible] [illegible]w Wing [illegible]," [illegible] 1971.

Region 5 Regional Development Commission and A. W. Research [illegible], "Mapping of Chlorophyll $\bar{a}$ Concentrations and Secchi Disc [illegible] [illegible] within Region 5 using Landsat Digital Data," January 1978.

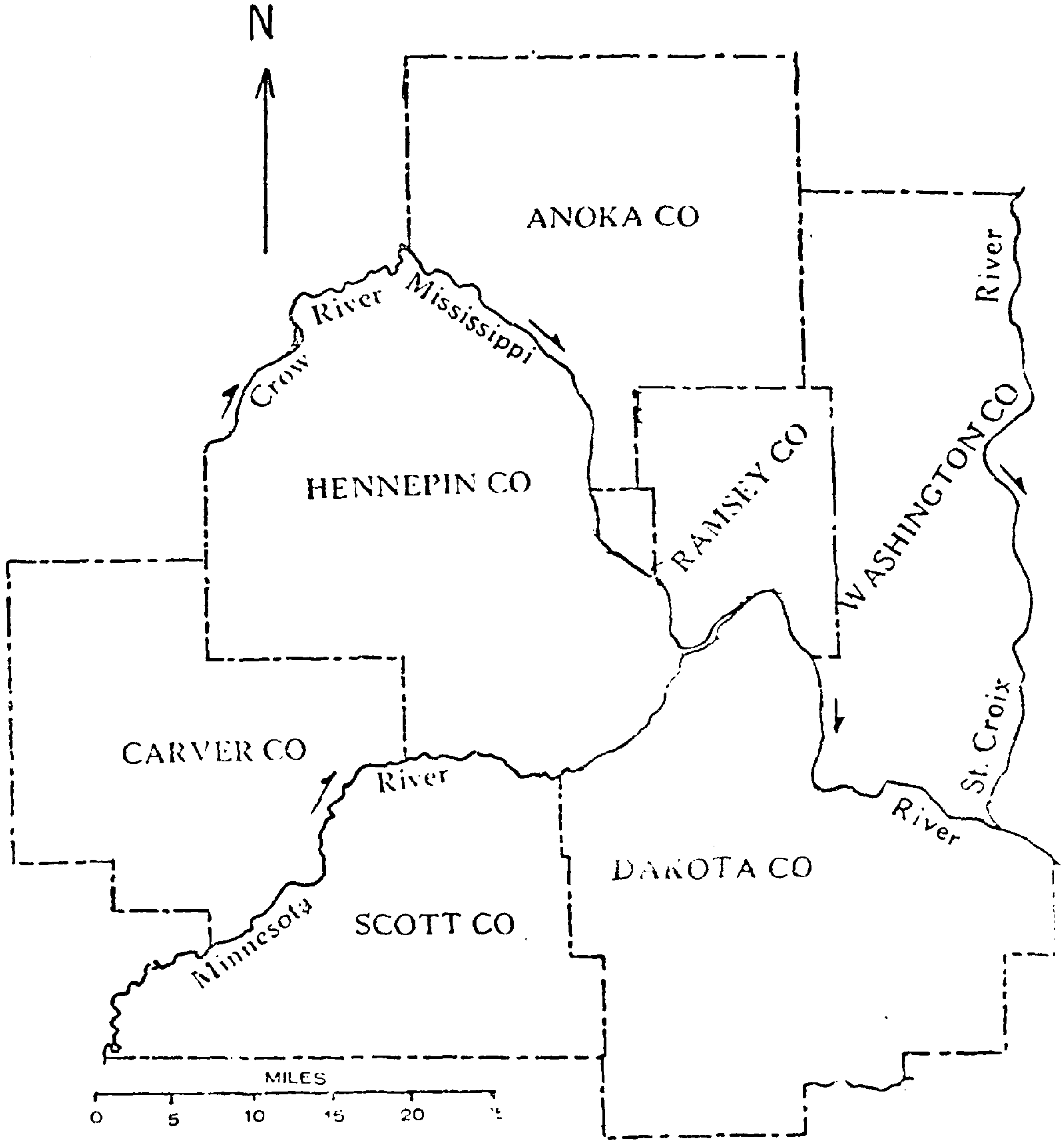
[illegible]apir[illegible], [illegible]oseph, Ph.D., "The Whitefish Chain of Lakes, Cro[illegible] [illegible] County, Minnesota (Water Quality Investigation)," J[illegible]nuary 1976.

U.S. Environmental Protection Agency, Region V, "National [illegible]trophication Survey, Report on Leech Lake, Cass County, Minnesota, Working Paper No. 105," 197[illegible].

TWIN CITIES WATER SUPPLY

BACKGROUND

The metropolitan Twin Cities area comprises a total of 2,968 square miles and is commonly referred to as the Seven-County Metropolitan Area. The seven counties are Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington (see the following figure). The 1975 population of this area was just over 2 million people. Water supply sources for the area consist of natural lakes, rivers, and groundwater. The major rivers flowing through or forming the metropolitan area boundary are the Mississippi, Minnesota, St. Croix, Rum, and Crow Rivers.



Twin Cities Metropolitan Area

The present plan of operation of the headwaters lakes does not provide for separate or special flow releases for Twin Cities municipal and industrial water uses. One proposed operating plan would allow additional flow releases to ensure that flows in the Twin Cities metropolitan area would not drop below approximately 1,600 cfs. (This flow is considered to be the minimum required to meet water supply and steam power needs in the Twin Cities area in the year 2015.) This flow would also meet navigation and irrigation requirements upstream of Anoka. Other plans would attempt to maintain higher flows at Anoka to satisfy Twin Cities area water quality requirements and to provide optimal flows for existing hydropower dams on the upper reach of the Mississippi River.

The Metropolitan Council and Twin Cities area officials have indicated they anticipate that water from the headwaters lakes storage, or from other sources will be needed to augment low flows in the Twin Cities area after the year 2000. Construction of the 9-foot channel Mississippi River navigation dams largely eliminated the need for navigation releases; however, during low-flow periods, such as occurred in the summer of 1976, the District Engineer requested voluntary curtailment of lockages. Lockages in the Twin Cities area were actually discontinued for several hours because of insufficient river flow. Headwaters releases were not increased above minimum conservation levels to offset this shortage, but this could have been done if the problem persisted.

The power companies with plants located along the Mississippi River have expressed concern over any change in headwaters lakes releases that could adversely affect power production. Through streamflow regulation from the 6 headwaters lakes, 15 hydropower plants have benefited with increased power output. Also, the seven steam-electric plants above the mouth of the Minnesota River rely on Mississippi River Headwaters releases for a dependable source of cooling water.

A permit system for appropriation of surface water and groundwater in Minnesota has been in effect since 1937. Irrigation permits for withdrawing surface water from the Mississippi River between the Mississippi River Headwaters Lakes and St. Paul have increased from 20 mgd (million gallons per day) (30 cfs) in 1970 to 27.4 mgd (42 cfs) in 1977. Irrigation withdrawals will continue to increase in the future and will compete with other uses during low-flow periods. The following table summarizes minimum Upper Mississippi River flow requirements (including the Twin Cities).

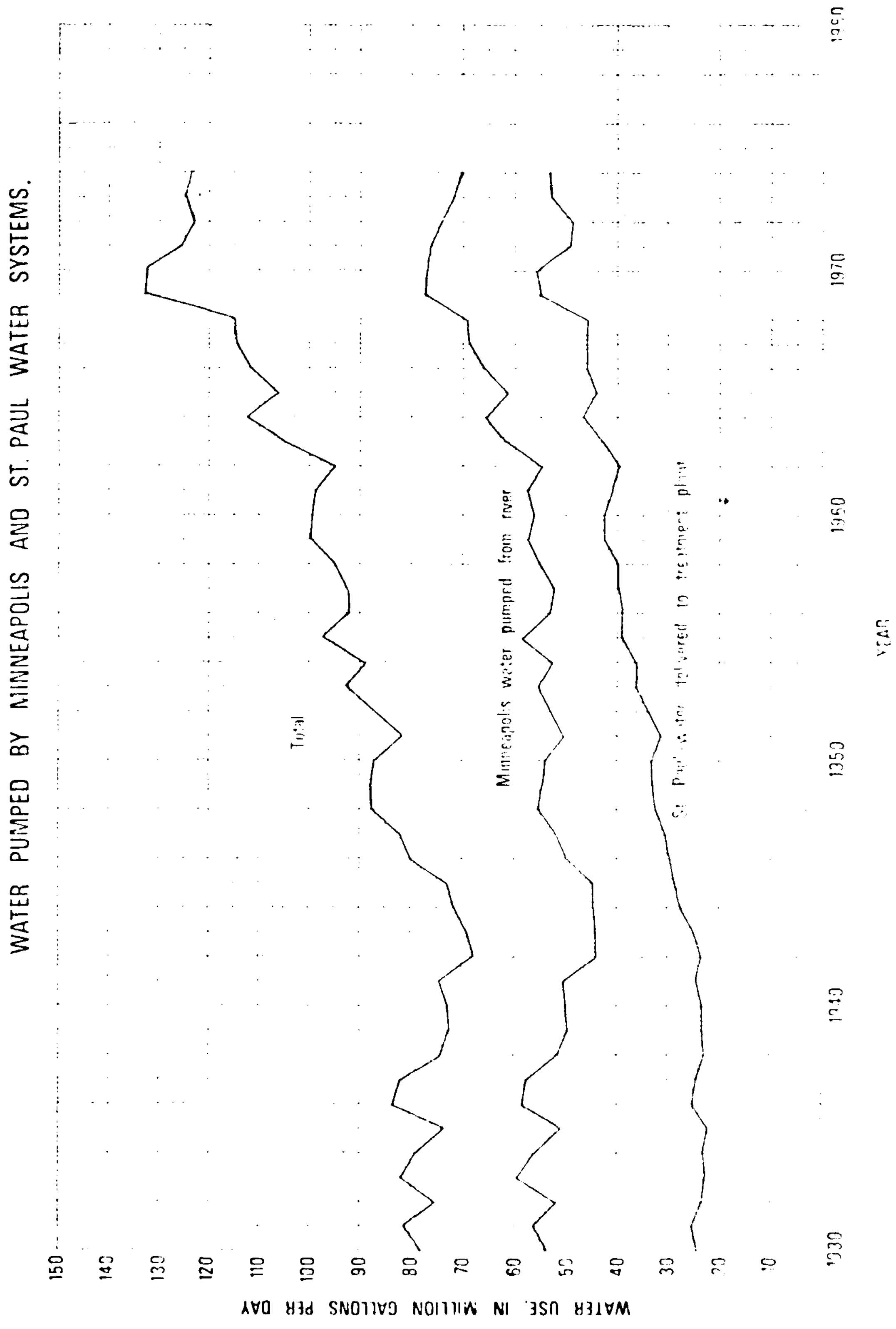
Preliminary summary of Upper Mississippi River low-flow water needs, including the Twin Cities

Use	Need (in million gallons per day) 1970	1980	1990	2000	2015
Navigation[1]	225	225	225	225	225
Irrigation upstream of Anoka[2]	20	47	67	87	120
Hydropower and steam electric demands[3]	437	437	437	437	437
Twin Cities area water supply					
Total[4]	306.1	381.2	509.1	679.2	1,010[6]
Surface water only[5]	101.1	151.2	189.1	256.2	485[6]
Amount required to meet surface water needs (irrigation, hydropower, and Twin Cities surface water supply)	558.1 (865 cfs)	635.2 (985 cfs)	693.1 (1,075 cfs)	780.2 (1,210 cfs)	1,042 (1,615 cfs)

(1) Minneapolis-St. Paul Level B Study, June 1977, page IX-3.
(2) 9 September 1964 summary of water quality and irrigation needs by Corps of Engineers.
(3) Based on peak cooling demand at Riverside steam power plant(from Level B, Minneapolis-St. Paul Water Supply Task Group Technical Paper).
(4) Minneapolis-St. Paul Level B Study, June 1977, Page V-5.
(5) From figure 1 (same source as footnote 3).
(6) Extrapolation.

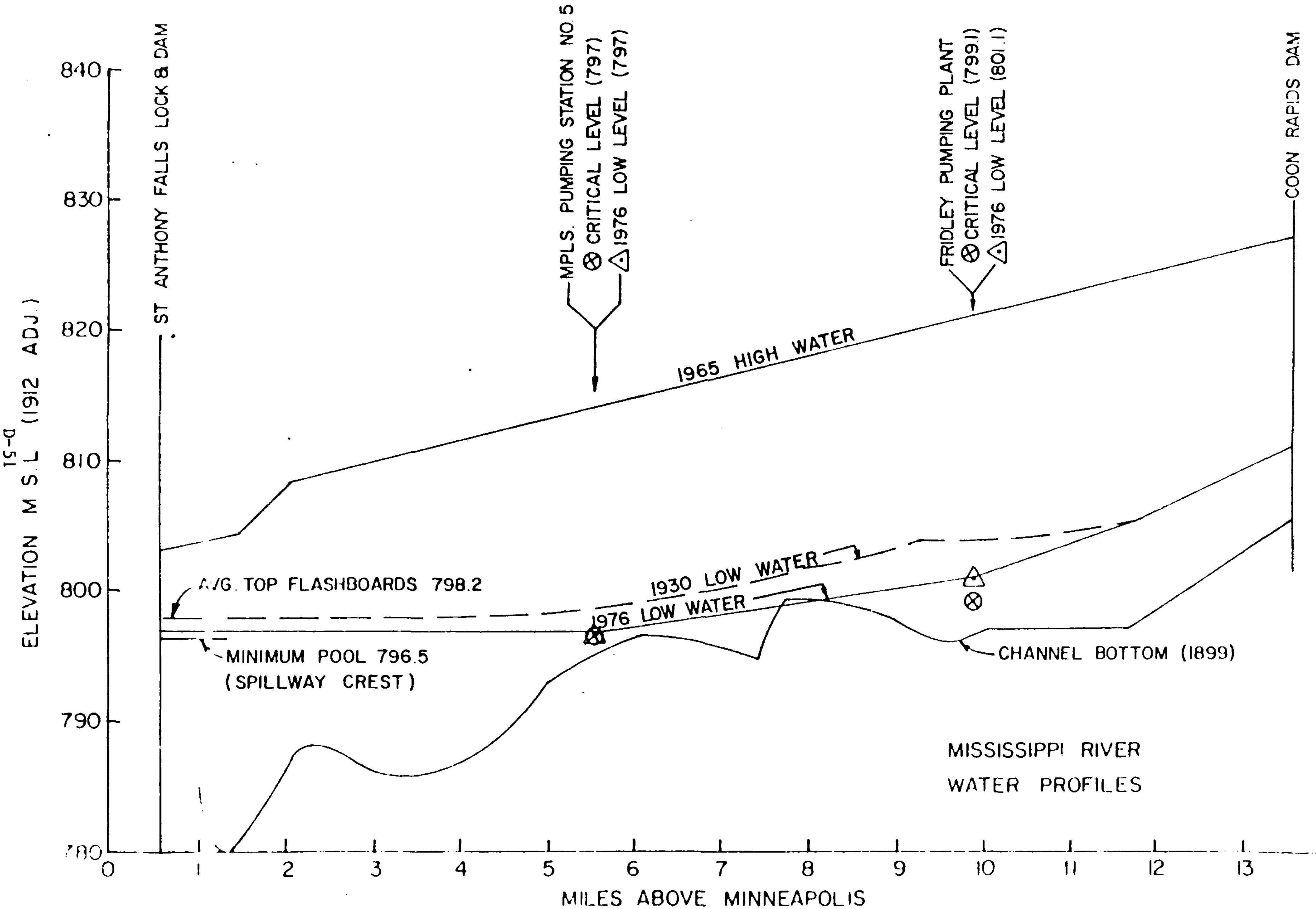
EXISTING DEMAND

Most of the area's water supply comes from either the Mississippi River or from groundwater. In 1973, the two largest cities, Minneapolis and St. Paul, supplied slightly over 1 million people, or half of the seven county area population, with water. The amount supplied averaged 120 gallons per person per day. Surrounding communities supplied by the two larger cities were (1) by St. Paul - the communities of West St. Paul, Falcon Heights, Lauderdale, Maplewood, Mendota Heights, Little Canada, Roseville, and Arden Hills and (2) by Minneapolis - the communities of Bloomington, Columbia Heights, Crystal, Golden Valley, Hilltop, Mornin - side, (which is part of Edina), and New Hope. The total water use by Minneapolis and St. Paul is shown on the following figure.



WATER PUMPED BY MINNEAPOLIS AND ST. PAUL WATER SYSTEMS.
Total
Minneapolis water pumped from river
St. Paul water delivered to treatment plant
WATER USE IN MILLION GALLONS PER DAY
YEAR
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1930
1940
1950
1960
1970
1980

St. Paul obtains its water from the Mississippi River at Fridley and from a chain of lakes lying 4.5 to 20 miles north of the city. Minneapolis obtains 100 percent of its water from the Mississippi River at Fridley. St. Paul's Mississippi River intake is farther upstream than the Minneapolis intake, even though the geographical locations of these two cities might indicate otherwise. See the following figure.


ST ANTHONY FALLS LOCK & DAM
MPLS. PUMPING STATION NO.5
CRITICAL LEVEL (797)
1976 LOW LEVEL (797)
FRIDLEY PUMPING PLANT
CRITICAL LEVEL (799.1)
1976 LOW LEVEL (801.1)
COON RAPIDS DAM
1965 HIGH WATER
1930 LOW WATER
1976 LOW WATER
AVG. TOP FLASHBOARDS 798.2
MINIMUM POOL 796.5
(SPILLWAY CREST)
CHANNEL BOTTOM (1899)
MISSISSIPPI RIVER
WATER PROFILES
ELEVATION M S.L (1912 ADJ.)
840
830
820
810
800
790
780
0
1
2
3
4
5
6
7
8
9
10
11
12
13
MILES ABOVE MINNEAPOLIS

Groundwater pumped in 1970 in the seven county area averaged about 2[illegible] mgd (million gallons per day), or 72 mgd greater than the combined surface water pumped by both the Minneapolis and St. Paul systems. Groundwater pumped from all aquifers during the peak demand part of the summer of 1970 was about 300 mgd. The distribution of groundwater use by category for 1970 shows that industry is by far the greatest user of groundwater, pumping 43 percent of the total. [illegible] communities in the metropolitan area were supplied by groundwater [illegible] that time.

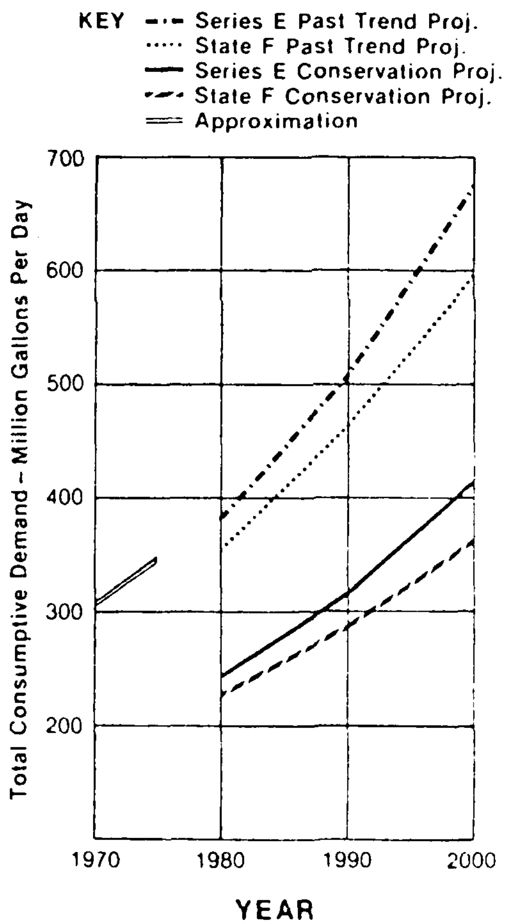
During 1976, Twin Cities municipal systems (especially Minneapolis) experienced problems with Mississippi River water withdrawals. The average monthly flows for August through November 1976 were greater than the estimated 985-cfs average monthly 1980 needs. Two principal factors contributed to the problem: (1) peak Twin Cities daily surface water consumption approached 300 cfs and (2) several problems with flow regulation on the Mississippi River disrupted the "run-of-the-river" flow regime in the Twin Cities. [illegible]

FUTURE DEMAND

Future water use demands for the metropolitan area were determined in the Level B Study in 1977. [illegible] demands are based on population projections by the U.S. Department of Commerce [illegible] Series [illegible] and population projections by the Minnesota State Planning Agency [illegible].

[illegible] were then obtained [illegible] industry earning projections. A conserv[illegible] developed assuming a 30 percent reduction in [illegible] reduction in commercial use. A 60-percent [illegible] and air conditioning use was assumed for the con[illegible] that water used for these purposes [illegible] projected water use trends for [illegible] on the following figure.

PROJECTED WATER DEMAND



Source: Level B Study

PROBLEMS IN MEETING DEMANDS

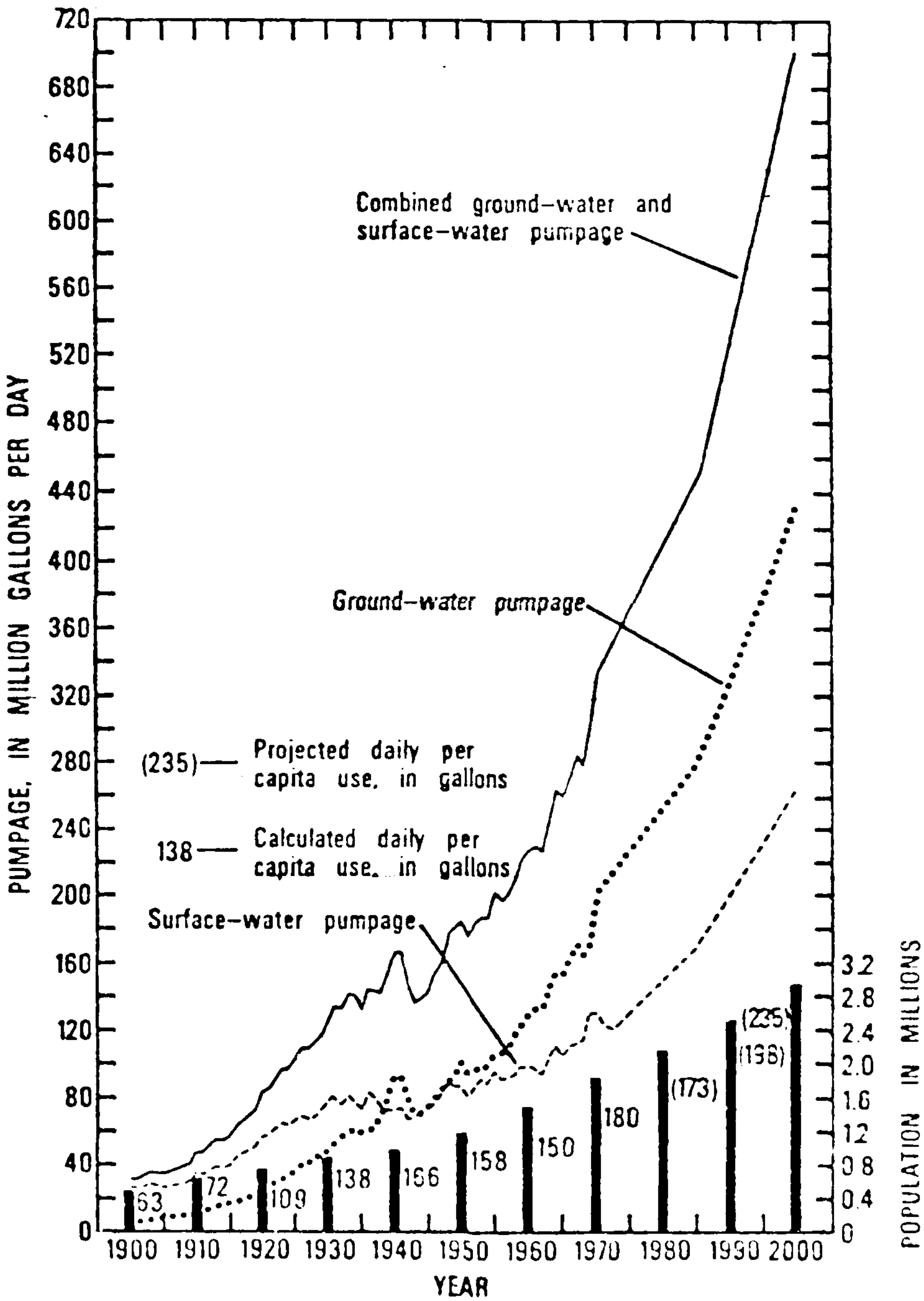
The Level B Study developed an initial plan evaluation using [illegible] management trends. This initial plan used a combined Minneapolis and St. Paul withdrawal of 380 mgd (year 1980 - Series E; year 2000 - State [illegible] conservation trend). When confronted with a 30-day, 100-year low-flow event, this plan produces flow deficiencies in the metropolitan area as shown in the tables on the following figure. The first table shows a deficiency of 260 mgd on the Mississippi River above the Minnesota junction. The second table shows a deficiency of [illegible] at the mouth of the Minnesota River. The third table shows a defiency of 948 mgd at the Metropolitan Sewage Treatment Plant for the 30-day, 100-year low flow.

HYPOTHETICAL STREAMFLOW BUDGET demonstrating flow deficiencies during severe drought projected to year 2000 using 30-day, 100-year low flow based on July, August, and September for the period 1935-71. (Withdrawals are represented by - values; additions by + values in MGD.

			CHANGE IN	ESTIMATED FLOW	
			Discharge	Discharge	Deficiency
Mississippi River					
Near Anoka				590	
Upstream powerplant use not represented during the base period			− 34	556	
St. Paul peak daily withdrawal during severe drought			−100	456	
Minneapolis peak daily withdrawal			−280	176	
Riverside powerplant, non consumptive peak cooling demand (2.6 mgd consumptive use from wells)			∓436	176	260 (60%)
Stream flow at St. Anthony Falls locks and dams for navigational requirement to operate locks			∓225	176	
Inflow (ground-water discharge, tributary inflow, etc.)			+125	301	
Streamflow at Lock and Dam No. 1 for navigation requirement to operate lock			∓225	301	
Minnesota River	CHANGE IN Discharge	ESTIMATED Discharge			
Near Jordan		90			
Inflow (ground-water, tributary, etc.)	+ 32	122			
Black Dog powerplant, non consumptive peak cooling demand (3.2 mgd consumptive use from wells)	∓417	122			295 (70%)
Subtotal at mouth of Minnesota River			+122	423	
Mississippi River					
At St. Paul				423	
Highbridge powerplant, peak cooling demand (2.3 mgd consumptive use from wells)			∓326	423	
Inflow (tributary and ground-water inflow between Minnesota River and Metro Power Plant)			+ 29	452	
Metropolitan Sewer Plant design standard minimum flow requirement 1400 mgd proposed, based on 7-day, 10 year low flow, by MPCA)					
Flow deficiency (augmentation needed to maintain water quality)					948 (68%)

Source: U. S. Geological Survey

Groundwater could be used to make up the expected surface water deficiency. However, there is always a concern that the aquifers could be overpumped and thus compound area water deficiencies. There is an increased trend to groundwater use in the metropolitan area already. The demand for groundwater is expected to increase faster than that for surface water based on historical and predicted population growth for the metropolitan area. The following figure shows a 450-mgd projected groundwater pumpage in the metropolitan area for the year 2000, as opposed to a surface water pumpage of only 260 mgd.



Historical and predicted population growth and approximate water pumpage in the Minneapolis - Saint Paul metropolitan area

Source: Level B Study

On the other hand, the potential sources of water [illegible] appear suitable for development as an alternative water source [illegible] St. Paul and Minneapolis. [illegible] estimates that the two principal aquifers underlying the Twin Cities have a sustained yield capacity of about [illegible] million gallons of water per day. These two underground sources, the Prairie du Chien-[illegible] and the Mt. Simon-Hinckley, could presumably supply the projected year 2000 groundwater demand of 430 and if the required [illegible] evenly distributed [illegible]

ALTERNATIVES TO SOLVE WATER [illegible] PROBLEMS

Four principal solutions or options were identified in the [illegible] Study. The four options involve using both groundwater and surface water sources. The first option would develop auxiliary groundwater supplies for Minneapolis and St. Paul using the two aquifers previously mentioned so as to reduce municipal withdrawals from the Mississippi River during low-flow periods.

The other three options would all [illegible] water sources. Option 2 would use the Mississippi River [illegible] Option 3 [illegible] develop [illegible] storage [illegible] near the metropolitan area, such as in the [illegible] Lake, some of which already are a part of the St. [illegible] Option 4 would divert water from the St. Croix River.

[illegible] Level [illegible] Study concluded that none of [illegible] adequate of themselves to solve the metropolitan area [illegible] deficiencies for all purposes. The study further [illegible] tion of [illegible] provide the best overall [illegible] for the metropolitan area.

[illegible] comparison of the four options [illegible] shown in the following table. Note that this [illegible] the options for [illegible] occurrence of a 30-day [illegible] low flow drought on the Mississippi River. The comparison is valid for the year 2000 and [illegible] the groundwater option [illegible] projected increase [illegible]

Item	Possible options - 30-day, 100-year low flow - year 2000 Do nothing	Ground-water	Mississippi R. headwaters	Rice Creek headwaters	Lake St. Croix
Augmentation (mgd)	0	155	500	100	500
Duration	0	Indefinitely	30 days	30 days	Indefinitely
Water quality shortage (mgd)	948	793	448	848	448
Municipal supply shortage (mgd)	0	0	0	0	0
Potential problem	Yes	No	Yes	Yes	Yes
Problem description	1930's drought	-	Possible contamination of supply source		
Cost [1]	0	$4,000,000	No new cost	$1,000,009	$50,000,000

[1] 1977 prices.

[illegible] the effect of special releases on the [illegible] delivered to the [illegible] release [illegible] magnitude would [illegible] each, in addition to normal [illegible] losses.

[illegible] REMARKS

[illegible] following [illegible] to resolve [illegible] needs during low-flow periods were [illegible]:

Action No. 1 - Mississippi River Headwaters [illegible] Revised [illegible]

The St. Paul District [illegible] Corps' Series [illegible] operations in the present regulation of the [illegible] lakes [illegible] [illegible] [illegible] of the [illegible].

[illegible] shows that [illegible] approximately 1660 [illegible] the period [illegible] were [illegible] below their [illegible] during the period [illegible] the [illegible] section of this [illegible].

[illegible] used [illegible] release [illegible] that the lake levels would [illegible] lower in [illegible] years with such a release plan [illegible] withdrawals from the lakes. [illegible] needed and consequently there would be no effect [illegible] lower levels on the [illegible].

low-flow releases would be needed. In a drought year, such as the 1930's, the lake levels would range from 0.5 foot to 3 or 4 feet lower.

A different approach was tried with the stage 3 analysis of the 1,600-cfs (plan 2) and other low flow release plans (plans 5 and 6). Rather than use flows from all six reservoirs to supply the minimum desired release, only Winnibigoshish, Leech, and Pokegama were used. (These three lakes have the most storage, and Pokegama Lake is in tandem with the other two.)

The results were much the same as in stage 2, only the added fluctuations attributable to low flow supplements were limited to Winnibigoshish and Pokegama Lakes. (Maximum lower levels at Winnibigoshish and Pokegama Lakes of 5.7 and 3.7 feet were then observed in 1935 and 19[illegible], respectively.) Generally, Winnibigoshish Lake levels would be 0.5 foot to 2 feet lower during years when low flow releases were required, and Pokegama Lake levels would be about 0.5 foot lower during the same years. This would occur in about 5 of the 47 years of record with the maximum drawdown levels coming during the 1930's drought.

In any event, a 1,600-cfs release plan was not recommended for adoption although it appears to be implementable with minimal adverse effects.

The St. Paul District considers this lake reregulation approach as an emergency measure that would require an order by the Governor of Minnesota each time a low flow augmentation release was made. There are unresolved problems with this proposal such as the apparent opposition to any low flow release plan by the Leech Lake Indians and lake property owners. These interests are generally opposed to any low flow releases from the headwaters lakes for any reason.

Action No. 2 - Twin Cities Metro Area Water Conservation Procedures

The St. Paul District worked with the cities of St. Paul and Minneapolis to develop a drought action or water conservation plan to cope

with Mississippi River low flows. St. Paul completed a plan in [illegible] 1980, but Minneapolis chose not to proceed because a [illegible] St. Paul plan takes into account reduction in consumption, increased surface water storage facilities, and construction of [illegible] capacity wells. In an emergency, St. Paul could possibly reduce its reliance on Mississippi River flows by 60 percent.

Action No. 3 - Increased Groundwater Usage

St. Paul has constructed two new high capacity test wells at Lake Vadnais that deliver a combined total of 10 [illegible]. These test wells [illegible] to be followed with construction of seven permanent wells that [illegible] about $700,000. Construction of these seven wells, which began in [illegible], should reduce St. Paul's Mississippi River demand [illegible] percent of the average daily 50-60 million gallon demand.

Minneapolis has conducted groundwater [illegible] but with [illegible] success. Minneapolis has [illegible] aquifers with possible connections to the Mississippi River. [illegible] located that would supply approximately [illegible] approximately 100 wells, [illegible] in the [illegible] [illegible] to shallow wells [illegible] contaminated [illegible] The shallow wells [illegible] River still rely on the same source [illegible] dependence from future low flow possibilities.

[illegible]

Operating plans 2, 3, and [illegible] were evaluated [illegible] supply varying amounts of water to the [illegible] [illegible]

[illegible] would [illegible] flows, respectively, at [illegible] [illegible]

minimum water requirements as mentioned previously. The 2,275 cfs is an alternative requested for evaluation by the Environmental Protection Agency and the Metropolitan Waste Control Commission. The flow constitutes a combined water supply and water quality alternative for supplying year 2000 water needs as identified by the Level B Study. The 4,800-cfs flow was requested by the Metropolitan Council and would constitute a year 2015 flow requirement to offset tertiary treatment needs in the Twin Cities area. (The 4,800-cfs figure at Anoka was also identified early in the study as a hydropower plan (plan 7). Therefore, plans 6 and 7 results are considered to be the same.)

STUDY CONCLUSIONS

The stage 3 analysis showed that a minimum flow of 1,600 cfs (plan 2, or year 2015 estimated minimum metropolitan area water supply needs) could be maintained at Anoka without exceeding the original minimum operating limits for five of the six headwaters lakes (Pokegama Lake's original minimum was exceeded by 0.3 and 0.5 foot in 1936 and 1934, respectively). However, three of the six would be drawn below their present lower operating limits during several periods in the 1930's to maintain the 1,600 cfs at Anoka (Winnibigoshish in 1934, 1935, 1936, and 1937; Leech in 1934 and 1936; and Pokegama in 1934 and 1936).

The 1,600-cfs flow is about the largest that could be maintained at Anoka. A somewhat higher flow of 2,275 cfs, for example (plan 5), would result in shortages at Anoka in 10 years, or 37 out of 564 months of record, or about 7 percent of the 47-year period of record.

The District recommends that neither plan 2 nor plan 5 be adopted; however, plan 2 might be used on an emergency basis. The District also recommends that the cities of St. Paul and Minneapolis develop alternate water supply sources and conservation techniques that would not only provide an added margin of safety during droughts but would protect the cities in the event of an unforeseen water quality problem, such as from a chemical spill or other accident.

Based on the stage 3 studies, it is recommended that the present plan of operation (plan 1) be retained as the accepted operating plan for the six headwaters lakes. In addition, it is recommended that a variation of the conservation plan (plan 9) for Winnibigoshish and Leech Lakes be incorporated in the recommended plan. These features are not in reality different from the present plan of operation, but are merely a refinement of that plan and are within the plan's operating limits.

Following a 13 April 1982 meeting with the Leech Lake Reservation Business Committee, it was decided that the Corps would continue to operate on the low side of the present summer operating range of 1294.5 to [illegible], but would attempt to stabilize Leech Lake at a level no higher than 129[illegible].

SUMMARY

The Minneapolis-St. Paul metropolitan area is faced with possible water deficiencies during drought conditions on the Mississippi River. Extended drought conditions similar to those of the 1930's would be especially damaging to Minneapolis, which currently takes 100 percent of its water from the Mississippi River. St. Paul, through its development of alternate water supply sources from surface storage and wells, is not as vulnerable. St. Paul's water conservation plan prescribes a possible 60-percent reduction in water demand during drought conditions.

It is imperative that the city of Minneapolis develop a water conservation plan and an alternate supply source to preclude serious [illegible] during a drought situation or in the event of an accident such as a hazardous waste spill. Releases from the Mississippi River Headwaters Lakes could possibly be used in drought situations to [illegible] flow of 1,600 cfs at Anoka without [illegible] severe economic loss. However, the Twin Cities [illegible] option as long-term solution [illegible] is a definite possibility [illegible] to make emergency releases to supply Twin Cities water [illegible] with the Governor of Minnesota after consultation with [illegible] interests, including representatives of the Leech Lake [illegible] Mississippi Headwaters Association.

STAGE 3 REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

APPENDIX E

PUBLIC PARTICIPATION AND COORDINATION

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

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PUBLIC PARTICIPATION AND COORDINATION

GENERAL

The current Mississippi River Headwaters study is a reinitiation of a study that was originally authorized in 1945. Limited study was done at least once in each decade since that time, with varying degrees of public involvement.

Public involvement during the current study was achieved through public meetings, progress reports, letters, and telephone contacts. The principal contact group for the Mississippi Headwaters geographic area was the Mississippi Headwaters Association. However, other groups such as the Aitkin Conservancy District; the Leech Lake Tribal Business Committee; the Whitefish Lake Property Owners Association; the Black Bear-Miller Lake Property Owners; and varied Federal, State, and county interests were actively involved at one time or another.

The public was most actively involved in the study during the early phases of work. Interest in the study waned somewhat once the stage 2 study report was completed in September 1979. Discouraging study findings, a lack of study funding in FY 1981, and lake operating plan computer modeling problems all contributed to decreased interest in the study after 1979.

MISSISSIPPI HEADWATERS ASSOCIATION

The Mississippi Headwaters Association was the principal contact group for this study. A 12-member board of directors represented the interests of concerned headwaters area residents. The 12 directors were from representative locations within the Upper Mississippi River basin, and included Aitkin, Minnesota. The association was re-formed in 1976 to provide effective two-way communication between the Corps of Engineers and the public.

As the study progressed, it became obvious that the Mississippi Headwaters Association should be assisted by other contact groups. A periodic progress report was also found to be essential to provide contact with the public from such a large geographical area. Many telephone and letter contacts were made with groups such as the Aitkin Conservancy District, the Leech Lake Tribal Business Committee, the Whitefish Lake Property Owners Association, the Black Bear-Miller Lake Owners group, the city water departments of Minneapolis and St. Paul, regional development commissions, the Minnesota Department of Natural Resources, and others.

The Mississippi Headwaters Association was retained as the titled contact throughout the study, although more work was undoubtedly conducted with the several other groups referred to above.

STUDY REPORTS

The initial report prepared for the study was a plan of study (POS) or stage 1 report dated January 1977. This report was followed by a draft preliminary stage 2 report in February 1978. A summary stage [illegible] report and appendixes were prepared in September [illegible], including a summarized version of an August 1979 contractor's report and appendixes. The contractor's report contained the computer modeling of the [illegible] Mississippi River Headwaters Lakes. The 3 study reports described above were interspersed with 7 progress reports which were sent to approximately 500 people and agencies interested in the study. Copies of the study reports were provided only to principal contact groups and area libraries.

MEETINGS WITH STUDY INTERESTS

The following list summarizes the coordination and public involvement meetings held during this study.

Date	Participants	Topic	Location
26 Aug 1976	Northern States Power	Availability of Mississippi River low flows	St. Paul
30 Aug 1976	Federal agencies, consultant	Public use development and resource management of the headwaters lakes	St. Paul
9 Sep 1976	Federal and State agencies	To form a Federal-State steering committee and review draft plan of study	St. Paul
20-22 Sep 1976	Public, consultant	Workshops on updating the headwaters lakes recreation management plans	Six headwaters lakes damsites
23 Sep 1976	Don La Garde, Leech Lake Tribe	Initial contact concerning study problems	Cass Lake
23 Sep 1976	Mississippi Headwaters Association	Review draft plan of study; association agreed to be focal coordination group	Walker
20 Oct 1976	Cass County residents, University of Minnesota Agriculture and Extension Service	Discuss proposed study	Walker
15 Dec 1976	General public, government agencies	Initial public meeting for study	Grand Rapids
12 Jan 1977	Aitkin Conservancy District, SCS, Aitkin County	Pine Knoll flood problem and headwaters study	Aitkin
2 Feb 1977	University of Minnesota Agric. Research, Federal, and State agencies	Commercial wild rice developments	Grand Rapids
23 Feb 1977	Dept of Transportation	Great River Road-headwaters study	St. Paul

Date	Participants	Topic	Location
23 Mar 1977	Minnesota DNR	Basic data on head-waters area	St. Paul
1 Apr 1977	Minnesota State Planning Agency	Potential damsites	St. Paul
6 Apr 1977	DNR-Fisheries	Proposed Leech Lake fishery study	St. Paul
9 May 1977	DNR-Brainerd	Black Bear-Miller Lakes flood problem	Black Bear-Miller Lakes
10 May 1977	City of Aitkin	Aitkin emergency diking	Aitkin
10 May 1977	Regional Develop-ment Commission (Region 5)	Land satellite imagery	Staples
15 Jun 1977	Mississippi Head-waters Assn	Presentation of preliminary study findings	Walker
18 Jun 1977	Whitefish Lake Property Owners Association	Lake obstructions and marking	Cross Lake
25 Jun 1977	Rabbit Lake Town-ship, SCS	SCS flood control proposal	Town Hall ner Riverton
28-30 Jun 1977	Lake residents	Lake damage interviews	Pokegama Dam
19 Jul 1977	Fish & Wildlife Service and Leech Lake Tribal representatives	Plan of study	St. Paul
2[illegible] Jul 1977	General public	Itasca County flood insurance public meeting	Grand Rapids
30 Jul 1977	Black Bear-Miller Lake residents	Flood problems	Black Bear Lake
1 Aug 1977	Federal and State agencies	Scope of work for Leech Lake photo interpretation contract	St. Paul
9 Aug 1977	DNE	Leech Lake subdiking	St. Paul
12 Sep 1977	Aitkin officials	Flood control plan - emergency dike	Aitkin
27 Sep 1977	Federal Power Commission	Mississippi River power benefits	St. Paul

Date	Participants	Topic	Location
28 Sep 1977	Region 5, Regional Development Commission	Land satellite imagery	St. Paul
9 Jan 1978	DNR-Fisheries	Direction of Leech Lake fishery study	St. Paul
27 Jan 1978	Leech Lake tribal representatives	Study progress, Leech Lake sub-impoundments, Leech Lake fishery and photo interpretation studies	St. Paul
6 Mar 1978	Aitkin Conservancy District, County, SCS	Feb 1978 draft stage 2 report findings	Aitkin
22 Mar 1978	Leech Lake Tribal representatives	February 1978 draft stage 2 report findings	St. Paul
2 Jun 1978	Rural Aitkin representatives, city of Aitkin (two meetings)	February 1978 study findings	Aitkin
17 Jun 1978	Whitefish Lake Property Owners Association	February 1978 draft stage 2 report	Cross Lake
28 Jun 1978	Mississippi Headwaters Association	February 1978 draft stage 2 report and Wild & Scenic River proposal	Walker
7 Sep 1978	Rural and city of Aitkin interests, county	Study damages analysis, lake operation, August-September 1978 agricultural flood	Aitkin
14 Sep 1978	Leech Lake Reservation Business Committee	Preliminary study results, dredging permits, Leech Lake wetland habitat study	Cass Lake
4 Oct 1978	Upper Mississippi River Basin Commission, DNR	Headwaters study	St. Paul
18 Jan 1979	HUD, DNR, general public	Flood insurance and headwater study public meeting	Aitkin
7 Mar 1979	Aitkin Citizens Committee, Aitkin Conservancy District	Study progress, efforts, findings	Aitkin
15 Jun 1979	Crow Wing County, Wolford and Irondale Townships, general public	Black Bear-Miller Lake project	Crosby

Date	Participants	Topic	Location
[illegible] Aug 19[illegible]	[illegible], general public	Flood insurance and headwaters study public meeting	Aitkin
[illegible] Sep 19[illegible]	Mississippi Headwaters Association, U.S. Forest Service, general public	Headwaters September 1979 study results, [illegible] River [illegible]	Walker
[illegible] 1979	North Central Division staff	Headwaters study check-in meeting	St. Paul
[illegible]	Aitkin Conservancy District and attorney	Headwaters September 1979 report findings	Aitkin
[illegible]	Minnesota [illegible] Commissioner and Department Heads, State Planning Board	September 1979 headwaters report briefing	St. Paul
[illegible] Jan 1980	Minnesota [illegible] Biological Services)	[illegible] evaluation of [illegible] headwaters [illegible] operating plans	St. Paul
[illegible] Feb 1980	Water Resources Seminar participants	Mississippi [illegible] water [illegible] study	University of Minnesota
20 Mar 1980	Leech Lake Tribal representatives, Mississippi River Parkway Commission	September 1979 [illegible] and future study direction	St. Paul
9 Apr 1980	National Park Service	Wild and Scenic River study coordination	St. Paul
3 Jun 1980	Surface Water Impoundments Symposium participants (Univ of Minnesota-Amer. Soc. of Civil Engrs)	Presentation of paper on headwaters study	Minneapolis
[illegible] 1980	U.S. Forest Service, Federal, State, county agencies	Chippewa Forest Plan, Corps studies	Cass Lake
[illegible] 198[illegible]	Leech Lake Tribal representatives	Staff findings, future coordination with tribe, conservation plan for Leech Lake	St. Paul

Date	Participants	Topic	Location
9-10 Oct 1980	Minnesota Chippewa Tribe, Federal agencies	Chippewa Tribe Business Development Conference	Grand Portage
16 Oct 1980	Minnesota Chippewa Tribal representatives	Future coordination with Leech Lake Tribe	Minneapolis
12 Nov 1980	Indian representatives, Minnesota DNR	Wild rice studies	St. Paul
12 Dec 1980	Leech Lake Reservation Planning Staff, DNR, and Ricing Committee	Wild rice studies	Cass Lake
29 Jan 1981	Leech Lake Tribal Attorney	Headwaters study - TV talk show	Bemidji
15 Jun 1981	University of Minnesota Agronomics Dept, Leech Lake Ricing Committee	Wild rice studies	Cass Lake
8 Jul 1981	Leech Lake Tribal representatives	"Conservation plan" for wild rice	St. Paul
29 Oct 1981	MVD, St. Louis District, St. Paul District, Minnesota DNR, Leech Lake Tribe	Downstream flow limitations	St. Paul

LETTERS

The next section contains pertinent letters from agencies and others involved in the study. The comments contained in the earlier letters generally respond to the September 1979 stage 2 summary report prepared by this office. These comments were incorporated or acknowledged in the present study report to every possible extent. More recent letters respond to the draft of the final feasibility report. Where appropriate, the recent letters of comment are followed by Corps responses.

No letter of comment on the September 1979 report or the August 1982 report was received from the Mississippi Headwaters Association. We believe the Headwaters Association favors the "status quo" with respect to headwaters lakes operation or a plan which would minimize flood and loss of business damages.

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

March 25, 1977

Colonel Forrest T. Gay, III
U.S. Army Engineer, St. Paul District
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

Dear Colonel Gay:

UPPER MISSISSIPPI RIVER HEADWATERS LAKES STUDY

Your letter of January 28, 1977 requested our Department's review of the revised Mississippi River Headwaters Lakes Plan of Study, giving special consideration to the proposed Days High Landing Dam.

For the Department's overall purposes, the present operation of the Headwaters Lakes has been satisfactory. However, realizing that various individual problems exist, we support a study to determine if improvements in operation of the reservoir dams could be made for mutual benefit. Generally, improvements to recreation, fish, wildlife, or flood control are of interest to our department.

Regarding the Days High Landing Dam, our department and the Corps of Engineers studied parts of the proposal several times in the past. Possible effects of the dam are better known than other study problems. In our judgement, the likely adverse effects to fish and wildlife from the dam would outweigh the questionable projected benefits to wild rice by a considerable margin. We feel it would be prudent not to restudy the Days High Landing proposal. We would be in favor of declaring that portion of the river as "Scenic" under the Bureau of Outdoor Recreation's Wild and Scenic River Program.

I trust this information will assist the Corps of Engineers in pursuing this study.

Yours very truly,

DIVISION OF WATERS

Gerald D. Seinwill

Gerald D. Seinwill, Director

GDS:bps

[illegible]
[illegible]
[illegible]
Federal Aviation Building
6301 34th Avenue South
Minneapolis, MN 55450

November 30, 1979 531.1

Col. William W. Badger
Department of the Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

Dear Col. Badger:

We have reviewed those portions of the Mississippi River Headwaters Lakes Study - September 1979 that might require comment from this Office, and found them to be satisfactory as now stated.

Sincerely,

John V. Graff
Meteorologist in Charge

Bemidji State University BEMIDJI, MINNESOTA 56601

DIVISION OF SCIENCE & MATHEMATICS
218 755-2920

December 3, 197[illegible]

Mr. Carl Stephan, [illegible] Manager
Mississippi River Headwater [illegible] Study
U.S. Army Corps of Engineers (St. Paul District)
St. Paul, MN 551[illegible]

Dear Mr. Stephan:

I received, under covering letter of 13 November 197[illegible], a [illegible] September 197[illegible] Stage 2 Study Report on the Mississippi River Headwaters Lakes Study. The letter solicits my comments which I [illegible]. The comments given below refer entirely to the [illegible] and not to Project Report No. 1[illegible] which [illegible].

In general the report appears to be [illegible] and [illegible] addresses the principal concerns of the [illegible] tive material which [illegible] the [illegible] ment alternatives. However, [illegible] as noted below. [illegible] the White Fish Chain [illegible] be considered.

1. Pages 1-[illegible]3. "Environmental [illegible]" a brief [illegible] the [illegible] discussion of mammals [illegible] ments [illegible] view of the Headwaters [illegible] Mississippi [illegible] 1973, pp. D-[illegible] and D-[illegible], [illegible] Studies, we [illegible] of these [illegible] non-game fish and birds, of which [illegible]. Indeed, these small mammals may, [illegible] the ecosystem particularly vulnerable to [illegible] changes in water-level. Most have only a small range of travel and cannot escape flooding by swimming or flying. [illegible] they provide a large part of the food supply for the more familiar [illegible] and raptorial birds, they should be considered in detail in the evaluation of the various proposed alternatives.

BIOLOGY CENTER FOR ENVIRONMENTAL STUDIES CHEMISTRY COMPUTER SCIENCE GEOLOGY MATHEMATICS PHYSICS

Mr. Carl Stephan
Page 2
December 3, 1979

2. Pages 13-15. The discussion of geology and soils appears to omit recognition that water quality in the Upper Mississippi is significantly affected by the soils which are drained by the river. Some highly discolored water enters the system in the Grand Rapids-Jacobson area (See p. D-IV-5 of the above-cited report). [illegible] water from turbid and [illegible] lation of water levels in the reservoir [illegible] on the existence of a [illegible] water [illegible] area.

3. Page 15. In the discussion of [illegible] bottom) to "natural ore", [illegible] the term "natural ore" should be replaced by "hematite".

4. Page 57. The problem of fecal coliform bacteria is mentioned. There should be some recognition that these problems tend to be highly localized, and that samples of Lake Winnibigoshish water had virtually no fecal coliform organisms in our 1973 sampling. The [illegible] contribution typical of cabins, resorts, and small communities with [illegible] sewage treatment systems tends to be significant only over small areas. The problem of water level manipulation can make such small problems much larger in cases where septic tank drainfields are flooded by the increased water level.

5. Page 61-63. The color interpretation of land photos from satellite cameras is not useful when, as in this case, only black and white pictures are supplied.

6. Pages 1[illegible]3-1[illegible]4. Aquatic weed control has important implications which are not noted in the Corps report. Both chemical and mechanical removal of weeds pose [illegible] with regard to [illegible] organisms to lake fisheries. In the case of chemical control, the nature and fate of the chemical products employed should be identified before this alternative is seriously considered.

7. Throughout the report annual costs are computed at a 6-[illegible] interest rate. [illegible] when treasury bills and other forms of government financing are now in the "double digit" category. It is not clear whether [illegible] the "first cost" is to be included in the annual cost, and whether future inspections and monitoring programs are to be charged to the cost of the various alternatives.

I appreciate having the opportunity to comment on the Stage 2 report.

Sincerely,

Charles H. Fuchsman, Director
Center for Environmental Studies

United States Department of Agriculture | Soil Conservation Service | 316 North Robert St., Room 200 St. Paul, Minnesota 55101

December 6, 1979

Colonel William W. Badger, District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

Dear Colonel Badger:

Thank you for the opportunity to review your September 1979, Stage 2 Study Report on the Mississippi River Headwaters Lakes Study and the Auxiliary Report prepared by the St. Anthony Falls Hydraulic Laboratory. We have no comments on either of the two reports.

Sincerely,

Harry M. Major
State Conservationist

cc: Jon V. DeGroot, ASC, SCS, St. Paul, MN

USDA:SCS:IEWILLINSON:WPC:idn 12/6/79

Metro Square Building, 7th Street and Robert Street, Saint Paul, Minnesota 55101 Area 612, 291-6359

December 10, 1979

Colonel William W. Badger
Corps of Engineers
1135 U. S. Post Office & Customs House
St. Paul, MN 55101

Re: Mississippi Headwaters Lakes Study, Stage 2

Dear Colonel Badger:

Thank you for the opportunity to review the Stage 2 Headwaters Lakes Study product. The Stage 2 report has been reviewed by Council staff and the following comments are offered.

Former Chairman Boland mentioned in his letter of May 23, 1978, we feel that releases from the headwaters lakes to augment flow for wastewater assimilation are usually as important as releases for drinking water augmentation. It was gratifying to see that the Stage 3 study will look at six to nine different low flow augmentation schemes. I would like to suggest that the flow range from 1600 to [illegible] cfs be reviewed as that range maximizing benefits to the Metropolitan Area. This range would thusly contain the 2275 cfs material by the MWCC in their letter of May, 1978. When costs associated with wastewater assimilation benefits are quantified, I am certain that the already favorable cost benefit relationship of the low flow scheme will increase greatly. Because of your committment to look at further low-flow releases, I will not point out further the many instances in the Stage 2 report where wastewater assimilation benefits could have given additional favorable review to the low-flow alternative. I trust that the Stage 3 work will adequately quantify these benefits.

The water supply augmentation question is also of major importance to this Metropolitan Area because our two largest cities and several of the surrounding suburbs served by them are dependent on Mississippi River water. The critical supply is that of Minneapolis because it has very little in-line storage and no supplemental groundwater supply. A serious drought or accidental spill that would force Minneapolis to close its intake valve would mean that the city could last for only 24 hours (maximum) before depleting supplies. St. Paul is fortunately in a better situation because of its lake storage system and a series of

we[illegible] that could supplement supplies. In either case, however, a major drought similar to 1976 could cause extensive social and financial disruption to 17 area cities serving over 870,000 people. Of the four options identified in the St. Anthony Falls Hydraulic Lab (SAFHL) report (p. 146) for reducing demand on the river for water supply, the one that calls for release of headwaters lakes water is currently the second most favorable, following use curtailment which can only result in limited overall savings. Storage in "special" reservoirs and withdrawal of more groundwater are limited options for St. Paul and non-existent options for Minneapolis. I would like to note, however, that both Minneapolis and St. Paul are exploring groundwater alternatives to supplement their systems. St. Paul has already put several wells into operation and Minneapolis is examining means available to do so. All of this leads to my recommendation that the Corps review its assessment of benefits derived in the SAFHL report. A figure of only $385 per month per cfs released (based on $0.60 per 1000 gallons) is not reflective of the actual costs that would exist if the two large suppliers were ever forced to discontinue withdrawal.

The other areas of benefit associated with low-flow augmentation, i.e., navigation, recreation, irrigation, power generation, and cooling, are also of great concern to us as a regional agency. I trust that all of the benefits associated with these uses will be quantified so that an adequate conclusion can be drawn relative to the importance of low-flow augmentation to the Metropolitan Area.

Finally, I would like to request that a scenario of operation procedure be placed in the Stage 3 report showing exactly how, when and by whom an actual augmentation would occur when needed. I understand that there was a great deal of confusion in 1976 as to how an actual release could be accomplished and who really had the authority to [illegible] such an action. This is very critical to such agencies as the Minneapolis and St. Paul Water Departments who must know how to proceed when a severe water shortage is anticipated and must have [illegible] such as the length of travel time from the headwaters and the volume of water expected from a release.

Once again, thank you for soliciting our comments. I am hopeful that they present our perspective and allow you to appreciate our concerns. I look forward to receiving your Stage 3 product.

Sincerely,

Eugene Franchett

Eugene Franchett
Executive Director
Metropolitan Council

EF/cmh

c City of Minneapolis Water Department
City of St. Paul Water Department
Metropolitan Waste Control Commission

COUNCIL FOR MINNESOTA ARCHAEOLOGY

OFFICE OF THE STATE ARCHAEOLOGIST
HAMLINE UNIVERSITY
ST. PAUL, MINNESOTA 55104

December 12, 1979

Mr. Carl Stephan
Manager, Mississ. River Headwaters Lakes Study
St. Paul District, Corps of Engineers
1135 U. S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Mr. Stephan:

This letter regards the Stage 2 summary report of the Mississippi River Headwaters Study of September 1979. We appreciate the opportunity to comment on this study. We have also recieved and reviewed "Cultural Resources Investigation of the Reservior Shorelines: Gull Lake, Leech Lake, Pine River, and Lake Pokegama", a shoreline survey of the major lakes with which the Study is concerned.

I concur with the statements on page 32 of the Study that state "Twelve ancillary lakes which are part of the reservior systems at Gull and Pine River Lakes still require surveys". The potential of these lakes in regard to cultural resources is very high, and they will be directly effected by any plan for maintenance of the Headwaters Lakes.

Statements on page 106 regarding the rate of site loss due to erosion and lakeshore development cannot be overemphasized. An active program of survey, assessment, protection, and mitigation can minimize the prevailing high rate of site loss.

It is evident that any of the alternatives proposed in this study will have some effect on cultural resources. Therefore, a program should be set up in which sites are assessed to determine significance regarding criteria of the National Register. Protection and/or mitigation of these sites should then follow.

If we may be of assistance as you develop plans for protection of the archaeological resources of this area, please contact us.

Sincerely,

[illegible]

FEDERAL ENERGY REGULATORY COMMISSION
CHICAGO REGIONAL OFFICE
230 SOUTH DEARBORN STREET, ROOM 3130
CHICAGO, ILLINOIS 60604

In reply refer to:

Your Reference: [illegible]
Our Reference: [illegible]

December 18, 1979

Col. William W. Badger
Department of the Army
St. Paul District Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

As requested in your November 13, 1979 letter, we reviewed the September 1979 report titled "Mississippi River Headwaters Lakes Study - Stage [illegible] Summary Report" covering studies on alternative operating plans for the six headwater lakes.

Our primary area of responsibility in the water resources field relates to licensing hydroelectric developments and safeguarding hydroelectric power resources. Since reservoir generating plans that would benefit power production have not as yet been studied, we have no comments to offer.

However, we note that reservoir operating plans that would optimize power production may be studied as part of the Phase 3 investigation. We strongly urge that such studies be undertaken because the [illegible] regulation provided by the six headwater reservoirs could increase the power output of 15 hydropower plants on the Mississippi River. [illegible] of these reservoirs to power production is supported by a recent [illegible] headwater benefits study which the Commission staff conducted [illegible] Upper Mississippi Reservoirs to determine the [illegible] benefits during the period 1925 - 1965. The Mississippi [illegible] serves as a source of cooling water for seven [illegible] plants [illegible] the mouth of the Minnesota River. These plants will have a total installed capacity of about 4,600 megawatts by 1985. Although a lack of cooling water for these plants is not a problem at present, a continued dependable supply is necessary. The impact on future downstream cooling water supplies should, therefore, also be considered in developing operating plans for the headwater lakes.

Although we recognize the need to limit the scope of the study to effectively deal with the numerous interests involved, the continuing emphasis on conserving the nation's fuel and energy resources would seem to dictate that consideration be given to operating plans that would increase the power production of downstream hydro plants and enhance the possibility of developing hydropower at the six existing reservoirs. The extent to which hydropower generation would be increased or decreased by the alternative operating plans should also be quantified.

Thank you for the opportunity to comment on this report.

Sincerely,

Lawrence H. [illegible]

Lawrence H. [illegible]
Regional Engineer

United States Department of the Interior

IN REPLY REFER TO:

FISH AND WILDLIFE SERVICE
TWIN CITIES AREA OFFICE
530 Federal Building and U.S. Court House
316 North Robert Street
St. Paul, Minnesota 55101

[illegible]

Colonel William W. Badger
District Engineer, St. Paul District
U.S. Army Corps of Engineers
1135 U.S. Post Office
St. Paul, Minn 55101

Dear Colonel B[illegible]:

This provides comments on the Mississippi River Headwaters Lakes Study, Stage 2 Summary Report, September, 19[illegible]. Although the report [illegible] the water [illegible] problems [illegible] with the [illegible] of the [illegible] headwaters lakes, we understand that operating plans will be [illegible] in greater detail in the Stage 3 study. Accordingly, we will provide additional comments [illegible] impacts of the project [illegible] operated [illegible] this [illegible] available.

Specific [illegible]

Page 21, paragraph [illegible] discussion of the timber or gray wolf, in [illegible] discussion [illegible] is misleading. The gray wolf is a federally designated threatened species subject to special protection. Attached is a copy of federally listed threatened and endangered species within the State of Minnesota for your information.

[illegible] They do not fulfill the requirements of Section 7 of the Endangered Species Act of 1973, as amended, which requires the Federal agency which authorizes, funds or carries out any action, to request of the Secretary of the Interior whether Federally listed or Proposed species are likely to be found in the project area. This can be done by writing to the Regional Director, U.S. Fish and Wildlife Service, Federal Building, Twin Cities, Mn [illegible].

Page 21 [illegible] does not reflect the most recent changes in the American Ornithologists' Union (A.O.U.) [illegible] list of North American Birds, a commonly accepted authority [illegible] the baldpate is now the American wigeon. A copy of the A.O.U. [illegible] for Birds [illegible] National Wildlife Refuge [illegible] enclosed for reference.

Page 23, paragraph 3: In addition to listing federally designated threatened and endangered species, we suggest contacting the Minn/DNR Non-game Wildlife Section for state designated threatened and endangered species as well as information on plants and animals deserving special management consideration. A publication you may find helpful is available from the Minn/DNR, "The Uncommon Ones," October 1975, 32 pp.

Page 128, final paragraph: Although we acknowledge that the alternative structural solutions to bank erosion control on the six Mississippi headwaters lakes are not economically feasible at this time, we are concerned about the adverse effects of long term erosion. While erosion reduction will be considered in overall lake operating plan revisions, bank erosion has been identified as a serious problem on all of the headwaters lakes and continues to degrade the aquatic environment. Further consideration should be given to erosion control alternatives on private properties including the placement of riprap on banks and beaches.

From the information at hand, it appears the present plan of operation for the headwaters lakes represents an equitable approach to satisfying resource demands without significantly altering established aquatic or terrestrial ecosystems. The Stage 2 study provides support for the maintenance of current management practices to resolve the [illegible] problem areas identified in the study.

We look forward to the opportunity to review the Stage 3 study of alternative operating plans. At that time we will recommend protection and/or enhancement measures deemed appropriate.

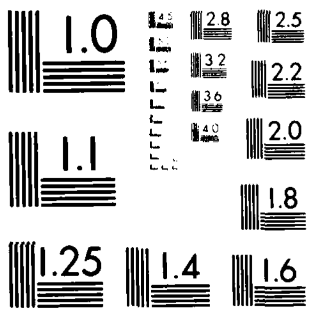
These comments have been prepared under the authority of and in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.) and are consistent with the intent of the National Environmental Policy Act of 1969.

Sincerely yours,

Attachment

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82 1/8

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AOU LIST

Reg 3 [illegible] List June 1979

Common Loon
Red-necked Grebe
Horned Grebe
Eared Grebe
Western Grebe
Pied-billed Grebe
White Pelican
Double-crested Cormorant
Great Blue Heron
Green Heron
Little Blue Heron
Cattle Egret
Great Egret
Snowy Egret
Black-crowned Night Heron
Yellow-crowned Night Heron
Least Bittern
American Bittern
Glossy Ibis
White Ibis
Mute Swan
Whistling Swan
Canada Goose
White-fronted Goose
Snow Goose
Blue Goose
Ross' Goose
Mallard
Black Duck
Gadwall
Pintail
Green-winged Teal
Blue-winged Teal
American Wigeon
Northern Shoveler
Wood Duck
Redhead
Ring-necked Duck
Canvasback
Greater Scaup
Lesser Scaup
Common Goldeneye
Barrow's Goldeneye
Bufflehead
Oldsquaw
White-winged Scoter
Surf Scoter
Black Scoter
Ruddy Duck
Hooded Merganser
Common Merganser
Red-breasted Merganser
Turkey Vulture
[illegible] Kite
Goshawk
Sharp-shinned Hawk
Cooper's Hawk

Red-tailed Hawk
Red-shouldered Hawk
Broad-winged Hawk
Swainson's Hawk
Rough-legged Hawk
Golden Eagle
Bald Eagle
Marsh Hawk
Osprey
Prairie Falcon
Peregrine Falcon
Merlin
American Kestrel
Spruce Grouse
Ruffed Grouse
Greater Prairie Chicken
Sharp-tailed Grouse
Bobwhite
Ring-necked Pheasant
Gray Partridge
Turkey
Sandhill Crane
King Rail
Virginia Rail
Sora
Yellow Rail
Purple Gallinule
Common Gallinule
American Coot
Semipalmated Plover
Piping Plover
Killdeer
American Golden Plover
Black-bellied Plover
Ruddy Turnstone
American Woodcock
Common Snipe
Whimbrel
Upland Sandpiper
Spotted Sandpiper
Solitary Sandpiper
Willet
Greater Yellowlegs
Lesser Yellowlegs
Red Knot
Pectoral Sandpiper
Sharp-tailed Sandpiper
White-rumped Sandpiper
Baird's Sandpiper
Least Sandpiper
Dunlin
Short-billed Dowitcher
Long-billed Dowitcher
Stilt Sandpiper
Semipalmated Sandpiper
Western Sandpiper
Buff-breasted Sandpiper

Marbled Godwit
Hudsonian Godwit
Ruff
Sanderling
American Avocet
Red Phalarope
Wilson's Phalarope
Northern Phalarope
Parasitic Jaeger
Glaucous Gull
Iceland Gull
Great Black-backed Gull
Herring Gull
Ring-billed Gull
Thayer's Gull
Laughing Gull
Franklin's Gull
Bonaparte's Gull
Sabine's Gull
Ivory Gull
Forster's Tern
Common Tern
Least Tern
Caspian Tern
Black Tern
Rock Dove
Mourning Dove
Yellow-billed Cuckoo
Black-billed Cuckoo
Barn Owl
Screech Owl
Great Horned Owl
Snowy Owl
Hawk Owl
Barred Owl
Long-eared Owl
Short-eared Owl
Saw-whet Owl
Chuck-will's-widow
Whip-poor-will
Common Nighthawk
Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Yellow-shafted Flicker
Red-shafted Flicker
Common Flicker
Pileated Woodpecker
Red-bellied Woodpecker
Red-headed Woodpecker
Yellow-bellied Sapsucker
Hairy Woodpecker
Downy Woodpecker
Black-backed Three-toed Woodpecker
Eastern Kingbird
Western Kingbird
Great Crested Flycatcher

Eastern Phoebe
Yellow-bellied Flycatcher
Acadian Flycatcher
Willow Flycatcher
Alder Flycatcher
Least Flycatcher
Eastern Wood Pewee
Olive-sided Flycatcher
Vermilion Flycatcher (accidental)
Horned Lark
Tree Swallow
Bank Swallow
Rough-winged Swallow
Barn Swallow
Cliff Swallow
Purple Martin
Gray Jay
Blue Jay
Black-billed Magpie
Common Raven
Common Crow
Black-capped Chickadee
Carolina Chickadee
Boreal Chickadee
Tufted Titmouse
White-breasted Nuthatch
Red-breasted Nuthatch
Brown Creeper
House Wren
Winter Wren
Bewick's Wren
Carolina Wren
Long-billed Marsh Wren
Short-billed Marsh Wren
Mockingbird
Gray Catbird
Brown Thrasher
American Robin
Wood Thrush
Hermit Thrush
Swainson's Thrush
Gray-cheeked Thrush
Veery
Eastern Bluebird
Townsend's Solitaire (accidental)
Blue-gray Gnatcatcher
Golden-crowned Kinglet
Ruby-crowned Kinglet
Water Pipit
Bohemian Waxwing
Cedar Waxwing
Northern Shrike
Loggerhead Shrike
Starling

Vireo

bler

Brewer's Blackbird
Common Grackle
Brown-headed Cowbird
Scarlet Tanager
Summer Tanager
Cardinal
Rose-breasted Grosbeak
Blue Grosbeak
Indigo Bunting
Dickcissel
Evening Grosbeak
Purple Finch
Pine Grosbeak
Hoary Redpoll
Common Redpoll
Pine Siskin
American Goldfinch
Red Crossbill
White-winged Crossbill
Rufous-sided Towhee
Lark Bunting
Savannah Sparrow
Grasshopper Sparrow
Le Conte's Sparrow
Henslow's Sparrow
Sharp-tailed Sparrow
Vesper Sparrow
Lark Sparrow
Slate-colored Junco
Oregon Junco
Dark-eyed Junco
Tree Sparrow
Chipping Sparrow
Clay-colored Sparrow
Field Sparrow
Harris' Sparrow
White-crowned Sparrow
White-throated Sparrow
Fox Sparrow
Lincoln's Sparrow
Swamp Sparrow
Song Sparrow
Lapland Longspur
Chestnut-collared Longspur
Snow Bunting

MINNESOTA

LISTED SPECIES

Mammals	Habitat	Distribution
Gray Wolf (T) *Canis lupus*	Northern Forested Areas	[illegible] - Beltrami, Clearwater, Cook, Koochiching, Lake, Lake of the Woods, Roseau, St. Louis Counties Peripheral Range - Aitkin, Carlton, Cass, Hubbard, Itasca, Kittson, Mahnomen, Marshall, Pennington, Pine Counties
Birds		
* Peregrine Falcon (E) *Falco peregrinus*	Breeding	Chisago, Cook, Dakota, Goodhue, Houston, Lake, Pine, St. Louis, Wabasha, Washington, Winona Counties
Bald Eagle (T) *Haliaeetus leucocephalus*	Breeding	Aitkin, Becker, Beltrami, Cass, Chisago, Clearwater, Cook, Crow Wing, Hubbard, Itasca, Lake, Lake of the Woods, Roseau, St. Louis Counties
	Wintering	Dakota, Goodhue, Houston, Sherburne, Wabasha, Washington, Winona Counties
Mussels		
Higgin's Eye Pearly Mussel (E) *Lampsilis higginsi*	Rivers	Lower Mississippi, St. Croix and Minnesota Rivers

* Peregrine Falcon breeding areas are taken from historical records and are to be considered potential breeding areas only. There are no active breeding sites in the State.

Minnesota Pollution Control Agency

January 7, 1980

William W. Badger
Colonel, Corps of Engineers
St. Paul District
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

Thank you for the opportunity to review and comment on the Stage 2 Study Report of the Mississippi River Headwaters Lakes Study. We have only a few, brief technical comments on the water quality description.

P. 54 - Mg/l is an incorrect unit with reference to plate counts. Plate counts are expressed as numbers of viable organisms per unit volume. Standards may be expressed as Most Probable Number (MPN) per unit volume. The Minnesota Water Quality Standard for recreational activities, including total body immersion is "fecal coliform organisms: 200 MPN/100 ml." (WPC 14, 15: 2A, 2B, 2C). The fecal coliform standard for waters classified suitable for domestic consumption (WPC 14, 15: 1B) is 10 MPN/100 ml.

TABLE p. 55 - Two lakes have been classified in WPC 25, Lake Winnibigoshish must meet 2B, 3B standards of WPC 15. Lake Pokegama must meet 2A, 3B standards of WPC 15. The other lakes would meet 2B, 2C, 3B, 3C, 4A, 4B, 5 and 6 standards as listed in WPC 14. The dissolved oxygen standard is misleadingly represented in the chart:

WPC 15: 2A standard is 7 mg/l minimum from October 1 to May 31. 6 mg/l minimum all other times.

WPC 14, 15: 2B standard is 6 mg/l minimum from April 1 to May 31 and 5 mg/l minimum all other times.

The chromium standard for WPC 14, 2B is 50 $\mu g/l$, not 5.0 mg/l. There is no color standard for WPC 14, 2B waters.

P. 61 - The LANDSAT scene as presented is not aligned on a N-S axis. North is presently at the left hand margin. It would also seem that a color-code legend is of limited use for a black and white picture.

(612) 296-7242
1935 [illegible]
[illegible]

Colonel William W. Badger
Page 2
January 7, 1980

P. 109 - With respect to a minimum guaranteed low flow in order to "decrease the required level of sewage treatment in the Twin Cities", section (c)(7) of WPC 15 states" allowance shall not be made in the design of treatment works for low stream flow augmentation unless such flow augmentation of minimum flow is dependable and controlled under applicable laws or regulation."

If you require any further assistance, please contact me or Virginia Reiner of my staff.

Yours truly,

John F. McGuire, P.E., Chief
Surface and Groundwaters Section
Division of Water Quality

JFM:sh

300 Metro Square Building, 7th Street and Robert Street, Saint Paul, Minnesota 55101 Area 612, 291-6359

January 8, 1980

Mr. Louis E. Kowalski, Chief
Planning Board
U.S. Army Corp of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Mr. Kowalski:

Thank you for your interest in soliciting our comments relative to the stage three portion of the Mississippi River Headwaters Lakes Study. It is indeed gratifying to see that our concerns are being acknowledged and that attempts are being made to address those concerns.

My letter of December 10, 1979 outlined why we believe water supply benefits should be quantified at a far higher rate than appeared in the stage two document. In summary, a benefit based on $0.60 per 1000 gallons does not begin to represent the costs that would be incurred by the cities of Minneapolis and St. Paul during a supply curtailment. Potential costs incurred by Minneapolis could include emergency connections with adjoining groundwater-supplied communities (such cross-connections currently do not exist), instigation of an emergency use program, possible connection to St. Paul for reservoir lake water use, and all of the engineering, distribution and planning activities that would have to accompany such actions. St. Paul is slightly more fortunate in that they have a reservoir lake system that stores about a one month supply of water (at summer level demand) and a supplemental well system at Vadnais Lake. Mississippi River supply curtailment would still, however, force St. Paul to institute an emergency use program, consider possible cross-connections with adjoining groundwater-supplied communities, possibly drop reservoir lakes to record low levels and undertake the same studies required by Minneapolis to prepare for an emergency shortage. During such a shortage, St. Paul would certainly

give its citizens and the communities it supplies higher priority than Minneapolis for use of reservoir lake water, although a spirit of cooperation likely would result in sharing of water to some degree. The point of the preceding discussion is that benefits associated with release of headwaters lakes water have to be viewed from the standpoint that curtailment will cost the cities of Minneapolis and St. Paul far more than that figure assigned by the study.

Similar arguments exist for each of the other uses identified in the December 10 letter. From a low-flow augmentation standpoint, maintenance of an assured flow means that discharges from industrial and municipal treatment facilities can be designed according to a particular standard with a fair amount of certainty. If your stage three evaluations show that releases to the Mississippi River can be increased so that more flow than 1600 cfs will reach Anoka, we can similarly evaluate treatment levels and perhaps expend less public funds upgrading discharges to advanced levels. Anticipated expenditures for the Metropolitan Treatment Plant alone are close to $200 million over the next five years. The public would benefit greatly if some means could be found to increase minimum flows and reduce treatment costs while still maintaining the environmental quality of the river.

From a navigation standpoint, decreased flows during the low-flow season mean less lockages and possible curtailment in barge movement. As happened in the summer of 1976, locks might be opened less often as a water saving measure. Again, the best way to assign benefits accrued from minimum flow releases is to look at lost capital associated with decreased barge movement both within and into/out of the Metropolitan Area.

Irrigation benefits I will leave to non-Metropolitan Area interests to address because we have little, if any, irrigation withdrawal directly from the Mississippi River. Recreational benefits will be extremely hard to quantify, but are perhaps best represented by hours spent on or near the river. Most lost benefits are going to be associated with boating, fishing and nature experience. Low water and decreased lockages means that many of the recreational boats on the river will have limited range and access. Fishing will of course decrease as water levels drop and water quality worsens. Trips to the river environs to bird-watch, explore nature trails and experience the river system will likely decline as the river deteriorates and becomes less attractive.

Power generation and cooling will be at highest demand during the naturally occurring low-flow periods. We suggest that the stage three effort explore the possibility of energy curtailments resulting from decreased availability of river water, and evaluate the loss of this benefit. It would also prove beneficial to evaluate losses from those power facilities serving the Region, but not necessarily within the seven counties, and loss of facilities that cannot be built because of the lack of acceptable minimum flows.

As for the conservation plan, the Council is not aware of any current effort, although the future presents several possibilities. We had a water conservation study proposed for 1979, but postponed its beginning because of the U.S. Water Resources Council change in water planning (Title III) orientation to now call for emphasis on water conservation. We are awaiting action by the WRC as to how funds can be passed through for such studies. The state will also potentially be responsible for statewide water conservation programs. To our knowledge, no current plan exists for the cities of Minneapolis or St. Paul. The area where we have defined the most immediate need is that of quantifying current useage. Obviously we cannot determine water-savings if we do not know what the current use is and what the possibilities for savings are. Any help in this area would certainly be most timely and would provide good data for future programs.

I would like to offer the assistance of the Council's Environmental Planning Division staff in any effort you pursue. The staff will be more than willing to meet with you or your staff to discuss our concerns and share our suggestions. We are quite interested in the headwaters study, so any guidance we can give or any information we can provide at this early stage will certainly benefit both of our agencies. The Council staff contact for continued input to the study will be Gary Oberts (291-6484).

Thank you again for your continued efforts to keep us involved in the headwaters study.

Sincerely,

Eugene E. Franchett
Executive Director

EEF:GLO:lmd
cc: Metropolitan Waste Control Commission
City of Minneapolis, Water Department
City of St. Paul, Water Department

LFRED PEMBERTON, SECRETARY-TREASURER
AMES MICHAUD, DISTRICT I REPRESENTATIVE

HARTLEY WHITE, CHAIRMAN
ROGER T. AITKEN, EXECUTIVE DIRECTOR
CAP PROGRAMS

NADINE C... DISTRICT II REPRESENTATIVE
CHARLES RAISCH, DISTRICT III REPRESENTATIVE

LEECH LAKE RESERVATION
BUSINESS COMMITTEE

BOX 308 • CASS LAKE, MINNESOTA 56633
218 335 2207

January 15, 1980

Mr. Rex Mayotte, Superintendent
Bureau of Indian Affairs
P.O. Box 97
Cass Lake, MN 56633

Dear Mr. Mayotte:

The following are our comments and suggestions to the Stage 2 Summary Report, and the St. Anthony Falls Hydraulic Report, both of which concern the operation of the Headwaters Reservoirs.

A point which is referenced several times in these reports, is the lack of information concerning fisheries and wild rice, and the impact to them by the four operational plans. An Upper Great Lakes Regional Commission Study, dated 1975, reveals a $20,000,000 wild rice industry in Minnesota. Nearly one fourth of these wild rice beds are located within the Leech Lake Reservation, at the top of the Headwaters Reservoir system. Since rice beds may be adversely impacted by fluctuating lake levels, an economic assessment should be made, and weighed against the four operation plans in the Stage 3 Report.

As human impact on the Headwaters Reservoirs intensifies in the next 30 years, the fisheries will sustain an increased fishing pressure. The economic interest here, is on a broad scale, as the Stage 2 Report has disclosed. Fisheries management planning should be included in the design of reservoir management planning.

We offer strong support for the conservation plan, which is mentioned on page 110 of the Stage 2 Report. Such a plan would promote water conservation measures, offsetting future demand, which is the basis for plan 4 of this study. We will work with you to design an operational plan based on the conservation of the Mississippi Headwaters Reservoirs to be included in the Stage 3 Report.

The recommendations for the Stage 3 Study, page 108 of Stage 2 Report, mentions an increased flow of 4,800 cfs, for the year 2015 at Anoka. The proposed purpose of such a volume is to provide water quality improvement in the Twin Cities area. An increased flush rate as a replacement for technological pollution abatement,

Mr. Rex Mayotte

Page 2

January 15, 1980

would be a circumvention of the federal clean water law. The Mississippi River should not be made a simple extension to municipal sewage treatment. A letter from EPA, page E-25 of Stage 2 Appendix, puts forth the federal legislation which governs water pollution control.

Our continueing cooperation in the Headwaters Reservoirs planning process will insure the maintenance of our reservation's integrity.

Mi-Gwitch!

Hartley White,
Tribal Chairman
Leech Lake Reservation

cc: Roger T. Aitken, Executive Director
Edward F. Fairbanks, Director Natural Resources
John Persell, Minnesota Chippewa Tribe
John Loftus, Special Operations

United States Department of the Interior

BUREAU OF INDIAN AFFAIRS

MINNESOTA AGENCY
P. O. Box 97
CASS LAKE, MINNESOTA 56633

IN REPLY REFER TO:
Real Property Mgmt.
1103-01
TRR 7-5

January 16, 1980

Colonal Bader
District Engineer
U.S. Army Engineer District
St. Paul
1210 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

Dear Mr. Bader:

Transmitted herewith are the comments of the Leech Lake Indian Reservation regarding the Mississippi River Headwaters Lake Study, Stage 2 Summary Report.

Our agency has also reviewed the document and our comments are in concurrence with those of the reservation. As you know, a large portion of the Headwaters Reservoir System lies within the boundaries of the Leech Lake Reservation, which was created through a treaty between the Chippewa Indians and the United States Government in 1855.

The basic rights inherent to a sovereignty still exist today within the exterior boundaries of the Leech Lake Reservation, regardless of the status of ownership on these lands. Prominent among these rights are those which pertain to the natural resources within the reservation. The Bureau of Indian Affairs, as trustee for the Leech Lake Band of Chippewa Indians, on behalf of the United States government, will protect the integrity of these resources to insure that they are not diminished.

On December 31, 1979, Interior Secretary Cecil Andrus, and Assistant Secretary for Indian Affairs Forrest Gerard, announced a policy decision governing the procedures for planning Indian Water Projects to comply with President Carter's Water Policy message of June 6, 1978.

This information will aid the Secretary in determining whether such projects merit departmental approval. In addition, this new policy requires, for the first time, an assessment by the affected tribe of the extent to which a particular project does or does not contribute to the social and economic well being of the Tribe. This assessment includes demographic effects on the reservation, effects on sacred sites, fish and wildlife habitats, and on archeological and historic sites.

The interaction between the operation of the headwaters reservoirs and the natural resources of the Leech Lake Indian Reservation should be a major consideration when alternate operating plans are considered by the U. S. Army Corps of Engineers. We hope that open lines of communication can be maintained at all times between your agency, our, and the government of the Leech Lake Reservation. We appreciate this opportunity to comment and stand ready to be of assistance if needed.

Sincerely yours,

Superintendent

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Chippewa National Forest
Cass Lake, MN 56633

3500

January [illegible], 19[illegible]

[illegible] W. [illegible]
[illegible], Corps of Engineers
[illegible], St. Paul District
[illegible] Custom House
[illegible] Paul, MN [illegible]

[illegible]:

[illegible] the following comments on the September, 1977 Mississippi River [illegible] Study Stage [illegible] Summary Report:

1. [illegible] of the Summary Report [illegible] state that a report [illegible] the results of a [illegible] year water quality sampling program [illegible] will be [illegible], 197[illegible]. [illegible] appreciate [illegible] a copy of this report when it [illegible] available.

2. [illegible] - We [illegible] with the recommendation [illegible] additional [illegible] of the [illegible]. Additional [illegible] the following alternatives:

   a. An alternative which would provide [illegible] additional [illegible] Twin Cities and [illegible] water [illegible] protection, recreation, and wild rice [illegible] Winnibigoshish and Leech.

   b. An alternative which would minimize lake property [illegible] Lakes Winnibigoshish and Leech.

   c. An alternative which would optimize water quality [illegible] the up-stream reservoirs.

3. On page 1[illegible], we agree that the current plan of operation [illegible] Lakes Winnibigoshish and Leech has resulted in a stabilization [illegible] in [illegible] occurrences, and that no use of structural [illegible] improvements should be undertaken for protection of large segments of shoreline. However, we recognize that current [illegible] threaten [illegible] developments on individual properties [illegible] form of stabilization may be cost-effective if limited to [illegible] sections of shoreline which immediately threaten such developments.

6200-11A 1-69

4. On page 158, under items a-e, we support the idea that no further investigation of the perimeter dikes is needed on Lakes Winnie and Leech. We envision no problems with detailed inspection, testing, or monumentation of these dikes, as long as such work involves minimal disturbance of existing vegetative cover. However, the concept of clearing brush and trees from dikes on Lake Winnibigoshish appears to contradict the planning objective of controlling bank erosion. Indeed, on the highly erosive soils characteristic of the shoreline of Winnibigoshish, vegetation and its associated rooting system is probably the most influential factor in holding the dikes together.

5. On page 218, the proposed dredging does appear to be the only alternative which would satisfactorily resolve the problem of insufficient flow capacity at the Leech Lake Dam. We are not aware, however, that significant problems with spring-time high water levels has been a recurring problem in recent years on Leech Lake, and would thus question the benefits to be gained by dredging. Is the [illegible] stage damage figure on page 184 representative of an average annual benefit in terms of property damage alleviated?

It is not obvious, from our viewpoint, that the benefits to be realized by increasing spring storage capacity would offset the adverse impacts on water quality of increased sediment generated from the dredging operation or the impacts of spoil disposal on the diked enclosure.

6. On page 197, we agree with the recommendation for no further studies of marsh development proposals below Leech Lake Dam during Stage [illegible]. [illegible] state, we are in favor of the no action alternative to maintain the integrity of the area as a canoe route. Our concerns with development of the area lie in a number of areas, including potential increases in nutrient loading likely to occur with development for wild rice production and possible disruption of eagle nests in the vicinity of the proposed activity.

The Sugar Point Bog subimpoundment is also not favorable in our opinion, due to the magnitude of the structural measures required, coupled with disruption of eagle activity in the area.

Unfavorable benefit cost ratios for the two development alternatives conclusively support selection of the no action alternative.

Sincerely,

J. E. Brewer

J. E. BREWER
Forest Supervisor

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
444 Lafayette Road, Space Center Bldg., St. Paul, MN 55101
(612) 296-0436

File No

January 31, 1980

Colonel William W. Badger
District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

The attached comments on the Corps of Engineers Stage 2 Study report on the Mississippi River Headwaters Lake are provided in response to your letter of November 13, 1979.

If you have any questions, please feel free to contact this office.

Sincerely,

DIVISION OF WATERS

Gene H. Hollenstein
Chief Hydrologist
Policy and Planning Section

GHH/ls

Attachment

cc: Kermit McRae

Comments on Stage 2 Summary Report
Mississippi River Headwaters Lake Study

Page 13 Groundwater

The first paragraph referring to many lakes being water table lakes hydraulically connected to the aquifers cannot be supported.

The paragraph should be rewritten since it gives the impression that groundwater use in the headwaters region is seriously affecting surface water levels. Although this may be true in a few specific local situations, it is not true as a generalization for the area.

Most of the groundwater use is centered in the sandplain areas where the major use is for irrigation. Discussion clarifying the occurence of groundwater under varying geohydrologic conditions is needed.

Page 18 - last paragraph

The statement regarding water deficiencies and water surpluses should be rewritten. It is suggested that the Corps contact Earl Kuehnast, State Climatologist, Department of Natural Resources, for suggested language.

Page 45 - second paragraph

Our records indicate only twelve hydroelectric power developments in the basin area. Nine hydroelectric developments are located on the Mississippi River at the; Twin City dam, Ford Motor Company; lower St. Anthony Falls, Northern States Power Company; Upper St. Anthony Falls (Hennepin Island), Northern States Power Company; Sartell, St. Regis Paper Company; Blanchard, Minnesota Power & Light Company; Little Falls, Minnesota Power & Light Company; Brainerd, Potlatch Corporation N.W. Paper Company; Grand Rapids, Blandin Paper Company; and Bemidji, Ottertail Power Company. Hydroelectric power developments are also located on the Crow Wing River at Pillager and Sylvan, owned by Minnesota Power

& Light Company and the Prairie River owned by Blandin Paper Company. The dams of the Elk River and Sauk River are not used for hydroelectric power development at this time.

Page 59

The statement of Page 59, third paragraph should be revised to indicate that 9 hydropower plants have benefited from streamflow regulation of the 6 headwaters lakes. The number of steam-electric plants in use in the basin area has not been checked by this office, but should be carefully checked by the Corps.

The statement regarding irrigation withdrawals should be changed to read as follows:

"Based on present trends, it is likely that irrigation withdrawals will continue to increase in the future and this may result in competition with instream users and other withdrawals. The magnitude of the problem will depend on water conservation and water management planning."

The maps on pages 46 and 47 should also be revised.

Page 64 - first paragraph

This statement regarding increased tourist use should be revised to reflect the possible impact of energy shortages on tourist travel which may change the effects on nutrients and eutrophication.

Page 69 - Bank Erosion

The first sentence should read, "Bank erosion on the headwaters lakes is caused by fluctuations in lake levels."

Page 72 - Other Problems & Needs

Add the following: It should be noted that permits will be required from the Minnesota Department of Natural Resources for any proposed work

which would change the course, current or cross-section of public waters. Of special concern is the area selected for deposition of dredged material in order to prevent filling of wetlands and destruction of wildrice beds.

Page 74

Third paragraph relating to more stringent land use management and development controls. The statement is very negative and it is suggested that it be rewritten to better relate to the existence of county shoreland management controls which should at least ensure that new development is not subject to flooding and will not cause additional water quality problems by better regulating waste disposal systems.

The paragraph should point out that there is a need for more comprehensive shoreland management programs closely related to those specific waters which are most heavily impacted by existing and new developments.

Page 76 - Desired Improvements

Third paragraph relating to power interests. The numbers should be revised as discussed earlier.

Pages 78, 79 & 80 - Formulation and Evaluation Criteria

Although there is a reference to possible solutions to flood problems on Page 82 in terms of nonstructural and structural alternatives, there is no reference to Non structural Alternatives and Criteria relating thereto in this section. Additional commentary and criteria regarding non-structural flood plain management planning should be included in the discussion on Pages 78, 79 and 80.

It should be noted that combinations of such non-structural methods such as, zoning, subdivision regulations, relocation, acquisition and flood proofing could be most beneficial if coordinated with involved local, state and federal agencies.

Pages 83 & 84 - Headwaters Lakes Operating Plans

Alternative 1 - the Present Operating Plan. It is recommended that the following statement be added to the discussion of Alternative 1:

"The present dam operation plan has been established based on a cooperative agreement between the Department of the Army and the State of Minnesota.

The plan is in compliance with requirements of Minnesota Statutes Section 110.49 which prescribes maximum and minimum stages and resultant discharges from each reservoir. (A copy of the statutes relating to the Headwater Lakes is attached).

Minnesota Statutes Section 110.53 provides for modification of the plan by the Commissioner subject to the following law:

110.53 MODIFICATIONS. It is recognized that experience may require changes in the elevations sought to be maintained on each of the headwater lakes. Consequently, once a plan has been put into effect, the commissioner is authorized to modify the stages sought to be maintained by modifying his plan with respect to any of the lakes involved to the extent of one foot in elevation according to the zeros of the present government gauges without the necessity of further or additional hearings; provided that in no event shall any departure from the elevation target be made so as to reduce any proposed stages below the minimums prescribed by section 110.49, clause (e) during the recreational season. Any modification of the plan established subsequent to the hearings herein provided which departs by more than one foot in elevation shall be placed into effect only upon further hearing proceeding upon the same formalities as the hearing hereinabove prescribed.

(1961 c 459 s 7; 1976 c 239 s 21)

ject datum, has been prepared under the direction of the commissioner of natural resources and approved by the South Dakota-Minnesota Boundary Waters Commission May 1, 1956. The construction of said project would make said works adequate and effective to conserve, control, and maintain the waters of said lake for the purposes aforesaid, would materially reduce the deposition of silt in said lake, and would substantially enhance the value of said lake for said purposes. Said project would promote the public health and welfare and would be in furtherance of the public interest in both of said states.

Subd. 2. **Commissioner of natural resources, duties.** The commissioner of natural resources is hereby authorized and directed to construct, maintain, and operate said project in accordance with said plan, and to acquire by purchase, gift, or condemnation as provided by law all lands and other property necessary therefor.

Subd. 3. **Supplementary law.** The provisions of this section shall not supersede or abridge any existing law not inconsistent herewith, but shall be supplementary thereto.

[*1957 c 749 s 1-3; 1969 c 1129 art 3 s 1*]

NOTE: See section 114.12.

110.47 HEADWATER LAKES OF MISSISSIPPI, REASON FOR CONTROL. It is the considered judgment of the legislature of the state of Minnesota that the regulation, control, and utilization of waters in the headwater lakes in the Mississippi River, including Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine River, (the Whitefish chain), Sandy Lake and Gull Lake are of tremendous economic importance and value to the state of Minnesota. It is further the considered judgment of the legislature of Minnesota that the utility of these lakes in aid of navigation has been very greatly diminished since the time of the establishment of the reservoirs, and that the economic values in utilization of these waters for state purposes has increased tremendously. These factors require the assertion on the part of the state of Minnesota of its rights to utilization and control of these water areas.

[*1961 c 459 s 1*]

110.48 JOINT FEDERAL-STATE CONTROL. The commissioner of natural resources is authorized and directed to enter into cooperative agreements with the United States of America acting through the department of the army for the joint control and regulation of these reservoirs within the principles hereinafter prescribed so as to effectuate control of the water elevations and the water discharges from the lakes in the interests of the state of Minnesota, subject only to any paramount need of waters from these sources in aid of substantial navigation requirements, and subject further to any substantial requirement of providing necessary flood control storage capacity as determined by the corps of army engineers.

[*1961 c 459 s 2; 1969 c 1129 art 3 s 1*]

110.49 PLAN FOR DAM OPERATION. The commissioner of natural resources is hereby authorized and directed to formulate a plan for the operation of the dams controlling each of the reservoirs hereinabove named which will:

(a) Seek to establish the water elevation on each of the lakes at the most desirable height, and to stabilize the stages at that point, insofar as practicable, during the recreational season in Minnesota;

(b) Give due consideration to providing for any reasonable fluctuations when desirable for the production of wild rice in the wild rice producing areas of these lakes;

(c) Take into account the elevations most desirable for the production and maintenance of wild life resources;

(d) Give due consideration to needs of water for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power production, and other purposes in the Mississippi river headwaters and downstream;

(e) Establish stages at which the water shall be maintained so far as practicable but basically recognizing the following minimum stages in reference to present zero on the respective government gauges:

Leech Lake 0.0

Winnibigoshish Lake 6.0

Pokegama Lake 6.0

Sandy Lake 7.0

Pine River 9.0

Gull Lake 5.0

(f) Prescribe maximum discharges at any time the elevations fall below such stages;

(g) Prescribe maximum elevations and amounts of discharge from each lake so as best to stabilize and effectuate the desired stages. Insofar as practicable, the following maximum lake stages shall not be exceeded:

Leech Lake 3.5

Winnibigoshish Lake 12.0

Pokegama Lake 12.0

Sandy Lake 11.0

Pine River 14.0

Gull Lake 7.0

[*1961 c 459 s 3; 1969 c 1129 art 3 s 1*]

110.50 POTENTIALS COMPREHENDED BY PLAN. The plan devised by the commissioner shall comprehend the following potentials:

(a) *The necessity for changing discharges to meet any emergencies resulting from unexpected or abnormal inflows;*

(b) The possibility of overriding requirements of the federal government for substant[illegible] discharges to meet reasonable and substantial navigation requirements;

(c) The overriding authority and needs as prescribed by the army engineers in discharging their functions of requiring additional storage capacity for flood control purposes.

[*1961 c 459 s 4*]

110.51 NOTICE OF PLAN; HEARING. Before the plan of operation for any headwater lake is put into effect, the commissioner shall publish a notice of hearing upon said plan for two weeks in a newspaper in each county in which the water areas to be affected lie. The hearing shall be conducted by the commissioner or his duly appointed referee. All interested parties shall have an opportunity to be heard, shall testify under oath, and shall be subject to cross examination by any adverse parties, and by the attorney general, or his representative, who shall represent the commissioner at said hearing. The hearing will not be governed by legal rules of evidence, but the findings of fact and orders, to be made and formulated by the commissioner, shall be predicated only upon relevant, material, and competent evidence. The findings of fact and orders incorporating the plan determined upon by the commissioner shall be published for two weeks in the same manner as the notice of hearing was published.

[*1961 c 459 s 5*]

110.52 APPEAL. Any riparian land owner or water user aggrieved by such findings shall have the right to appeal within 30 days of the completion of publication to the district court of any county in which the regulated water lies, which appeal shall be determined by the court on the record made before the commissioner of natural resources. Issues on any such appeal shall be the legal rights of the parties and the further question as to whether the findings of the commissioner are reasonably supported by the evidence adduced at the hearing.

[*1961 c 459 s 6, 1969 c 1129 art 3 s 1*]

Whitefish Lake Channel Obstruction and Marking

Page 168 - Alternative 1 No action

The second paragraph points out that <u>all lakes are interconnected at normal levels by a navigable channel</u>.

This infers that the problem is only during low water periods and is not a persistent problem. Furthermore, the sentence relating to the failure of the 1976 cleanout effort of the Big Trout Lake channel points out a major problem in attempting to maintain an open channel during low flow periods since the channel silted in rapidly.

This problem should be emphasized in the report.

Page 169

The discussion of decreases in property values should be better substantiated by showing the differences in asset values around the various lakes, the actual real estate values around each of the lakes and the total area of <u>developable shoreline</u> around each of the lakes. The statement at the bottom of Page 169 indicates that the values would decrease "<u>if complete access to the main Whitefish Lake were lost</u>" but the fact is that the losses only result during low water periods as noted by the statement of Page 168 that "<u>all 3 lakes are interconnected at normal levels by navigable channels</u>." Thus, the data, which do not appear to be adequately documented and supported, do not properly reflect the situations existing.

Page 170 - Alternative 2

The table showing controlling water depths indicates that only 2 lakes, Big Trout (1.7 feet) and Loon (2.0 feet) have inadequate depths for boat navigation, except possibly for sail boats which likely require 6 foot depth.

The assumption regarding a 6 foot depth should be clarified. How many sail boats are in use on the lake?

Page 171 - Alternatives 3 and 4

Both relate to Hazard Marking and Accidents. How many accidents have occurred as a direct result of inadequate channel depth and what is the frequency of occurrence?

Page 172

This refers to a need for a 6 foot deep channel with 75-feet bottom width. Again there are no data shown to justify the depth and width stated.

Page 174 - Alternative 6

The use of riprap jetties in lakes is normally not allowed because of interruptions of off shore drift and subsequent environmental problems.

Alternatives 7 and 8 - The same comments would generally apply.

Pages 182-189

Leech Lake Dam Inlet Channel Restrictions. There is concern regarding the implementation of Alternative 2 (dredging) under the District's continuing operation and maintenance program in respect to deposition of the dredged material. The District should coordinate these efforts with the DNR to assure that the disposal of dredged materials will not create adverse environmental problems.

Pages 197-215

Aitkin Area Flood Control. The Department of Natural Resources supports the development of a comprehensive non-structural flood plain management program as recommended by the Corps.

Attached herewith are comments the DNR, Division of Fish and Wildlife have on the study.

Review of the Headwaters Reservoirs
Stage II Study

The study two plan recommends that the fish and wildlife agencies provide further guidance because the environmental losses are not included. These recommendations can be divided into two parts, (1) effects of proposed structural modifications, and (2) effects of the proposed operating plans.

There are four operating plans which have been proposed in the stage two headwaters study report, and they are (1) the natural plan which is a return to natural conditions, (2) the present operating plan, (3) the low flow plan which is the present plan modified to provide a minimum flow of 1600 cfs at Anoka, (4) and the high flow plan which is designed to provide flood protection at Aitkin. The effect of these plans on reservoir stages was computed for the years 1932 through 1976, a period of 45 years. The first plan was developed for comparative purposes and was judged to be undesirable. Excluding fish and game considerations, the high flow plan was found to be poor compared to the present and low flow plans which appeared to be approximately equal.

The reservoir stage curves were evaluated by spawning level recommendations, maximum levels, and minimum levels. The hydrographs were analyzed to determine the number of years the reservoirs were within the guidelines established by the Division of Fish and Wildlife in 1963. From this data the probability of occurrance (percent of years) can be calculated and the results analyzed. There were four reservoirs with specific spawning levels to be reached by April 15 to 20; Leech, Sandy, Pokegama, and Winnibigoshish. The four plans rank (1) low flow because it maintains a minimum flow of 1600 cfs at Anoka, (2) present plan, (3) high flow plan, and (4) natural flow plan. Using all three factors the ranks turn out about the same. The main advantage of the low flow plan over

the present plan is that the low flow plan maintains a minimum discharge of 1600 cfs at Anoka (about 22 percent of average flow) and that the scores were high in all four reservoirs with spawning recommendations.

Getting water out of Leech Lake Reservoir appears to be a problem which needs attention, but how the dredged materials are disposed of could cause some serious environmental problems so an adequate disposal plan should be developed. The damage curves in the appendix suggest that Leech Lake could be operated 0.5 feet higher in the summer. Lowering the summer operating level 0.5 feet as suggested in the Governor's letter should be continued. It should be noted that obstructions similar to those noted in Leech Lake occur in Pokegama Reservoir at the outlet of the Blackwater-Gould Lake complex and at the outlet of Pokegama Lake. The work at Leech Lake seems pointless if the Pokegama Reservoir problems aren't aleviated. Perhaps dredging and/or the alternate outlet suggested under erosion control below Pokegama should be considered in the stage 3 report.

The current Leech Lake contract study indicated that the 1963 Fish and Wildlife recommendations are satisfactory. On page 110 a different plan is suggested for managing the water levels on Sandy. The question is how would this plan effect the water levels needed for spring fish spawning.

In general, the plans had the most adverse effect on Pokegama and Sandy reservoirs. The present plan has the highest adverse effect on Sandy and the effect is not as great with the low flow plan.

The list of modifications needed were as follows:

1. A dam at Day's High Landing to control water levels.

   The decision by the Corps is in accord with the current views of the Division of Fish and Wildlife. There are studies on file supporting this view.

2. A dam below Black Bear and Miller Lakes to prevent flooding.

   No comments.

3. Fixing the perimeter dikes on the headwaters reservoirs.

   We have no objections to fixing the dikes.

4. Remove channel obstructions on the Whitefish chain of lakes.

   Where large flows of water are absent it might be difficult to keep channels open. A channel to Sugar Lake adjacent to Winnibigoshish filled with sand after it had been established.

5. Remove restrictions in the Leech Lake dam inlet channel.

   Establishing a better outlet channel to the Leech Lake dam seems to be necessary, but care should be taken where the spoil is placed. Any proposed disposal site should be approved by the DNR.

6. Marsh restoration downstream from Leech Lake dam.

   While this restoration is basically a good project it does not appear to be practical as proposed.

7. Erosion control in the headwaters reservoirs.

   Protecting banks from erosion is always a good idea. Normally rocks or similar devices are placed on the banks to protect them from excessive wave action. It might be possible to break the force of the waves with an artificial rock bar parallel to eroding banks. This could be placed in water 2 to 4 feet deep with the top about a foot below normal summer water levels and would also serve as habitat for fish and other aquatic organisms. Sandy shallows without aquatic plants are usually unproductive.

8. Erosion Control downstream from Pokegama.

   Having an additional outlet at the eastern tip of Pokegama Lake is a good idea, but the gain would be more precise control of water levels rather than the erosion control as suggested.

rsh construction in Leech Lake reservoir.

veloping the large marshes as proposed appears to be impractical at is time. The recent study suggests additional northern pike spawning ea is not needed.

f these, fixing perimeter dikes and removing restrictions in the Leech Lake let channel were considered for further consideration in the stage three The erosion control problem in the headwaters reservoirs is considered f the operating plan.

Percent of the Time the Reservoirs had Appropriate
Water Levels at Spawning Time (April 15-20)

Reservoir	Natural Plan	Present Plan	Low Flow Plan	High Flow Plan	Ave. of Four Plans
Pokegama	2.2	31.1	33.3	28.9	23.9
Sandy	-	26.7	35.6	35.6	32.5
Leech	4.4	60.0	60.0	44.4	42.2
Winnibigoshish	0.0	55.5	53.3	0	27.2
Mean	[illegible].2	43.3	43.3	27.2	31.45
	2.2	16.7	16.9	19.3	8.0
CV	100	3[illegible]	34	71	25

Percent of Years Reservoirs Meet
Fish and Game Operating Standards

Reservoir	Natural Conditions	Present Plan	Low Flow Plan	High Flow Plan
Leech	38.4	74.9	74.9	72.4
Winnibigoshish	33.3	68.9	67.3	30.4
Pokegama	7.8	39.6	40.7	36.2
Sandy	--	37.8	37.8	14.0
Pine	50.0	100.0	98.9	100.0
Gull	20.0	97.8	95.6	97.8
$\overline{X}$	29.9	69.8	69.6	58.4
SX	16.4	27.1	26.1	36.7
CV	55	39	38	63

OFFICE OF THE CHAIRMAN

STATE OF MINNESOTA
WATER PLANNING BOARD
600 AMERICAN CENTER BUILDING
150 EAST KELLOGG BOULEVARD
SAINT PAUL, MINNESOTA 55101

(612) 296-1424

February 5, 1980

Colonel William W. Badger
District Engineer
Corps of Engineers
1135 U.S. Post Office
St. Paul, Minnesota 55101

Dear Colonel Badger:

I appreciate the opportunity to review your Headwater Lakes Study Stage 2 Summary Report. Although the Water Planning Board has no direct involvement in the management of these lakes, it does have authority to conduct state-level water planning and to coordinate activities of state agencies.

You should be aware that the Water Planning Board (or its successor after July 1, 1980) is intended to serve as a forum for developing unified state policies among state water management agencies, and can provide a forum for review of your Stage 3 efforts. Because your Stage II report is informational and requests comments only on further development of the study, I do not believe Board action is appropriate at this time.

However, I am concerned that results of Stage III may be controversial and will require sufficient analysis to thoroughly evaluate the economic and environmental impacts of low-flow augmentation for the Twin Cities. I believe that Stage III should attempt to quantify all costs and benefits associated with the loss/provision of water supply for the Twin Cities (and other municipalities), the effects of a "guaranteed" low-flow on treatment plant operation and Mississippi River water quality, and the resultant effects of various augmentation plans on the use of the headwater lakes. Such information is essential for state agencies to evaluate the trade-offs among optional operating plans.

I am also aware that "optimization" techniques can be used to identify optimal reservoir release schemes, if the system constraints and cost or damage functions can be derived. Does the complexity of HEC-5C rule out such an approach?

Finally, I would like to encourage you to involve our state agencies throughout the conduct of Stage III. This could easily be arranged through meetings of the Water Planning Board and should facilitate state approval of a release plan. If desirable, we also have the ability to form "task forces" of representatives of concerned state agencies to assist you. Please contact Brandt Richardson (297-2376) if we can provide further explanation or assistance.

Again, thank you for the opportunity to review your report.

Sincerely,

Thomas Kalitowski

THOMAS KALITOWSKI
Chairman

TK:pm
cc: Gene Hollenstein, DNR
Gary Botzek, Office of the Governor
Kermit McRae, Office of the Governor

AITKIN DRAINAGE AND CONSERVANCY DISTRICT

AITKIN, MINNESOTA

February 15, 1980

Mr. Carl Stephan, Study Manager
Corps of Engineers
St. Paul District
U.S. Post Office & Custom House
St. Paul, MN 55101

Dear Mr. Stephan:

Re: Aitkin Drainage & Conservancy District

After reviewing the Mississippi River Headwaters Lakes Study, Stage 2 Summary Report, dated September 1979, I would like to make the following comments:

The Flood Control Plan for Aitkin (Alternative #3) would be the best plan of operation for the Aitkin area. The plan suggests that some flood protection for Aitkin is provided by established maximum water levels that can be tolerated by lake property owners. The chart on page 35 of the before-mentioned study would show that the elevation of the legal flowage limits has seldom and in some instances never been reached. A flood control plan for Aitkin where the full legal flowage limits were exercised on the lakes would provide for Aitkin additional flood protection.

The operating plan comparison on page 89 of the Stage 2 Summary gives little applicable information. Losses incurred by the headwater lakes and Aitkin are determined by using records up to 1978 and a 1977 price level. The losses at Anoka are determined on their water needs of the year 2015. We feel that the damages in Aitkin should reflect the enhanced value of the area and that the operating plan comparisons should all be set in the same time frame.

I feel Aitkin Drainage and Conservancy District should again present here the position that it has always taken since construction of the flood control channels. When the reservoir lakes were created, the United States took flowage

easements which we feel should be fully exercised in the regulation of waters during flood periods. If the reservoirs are not used to full easement capacity, then the Aitkin area is being denied some of the benefits of the flood control project. That was not the contemplation of Congress when the funds were appropriated.

On the other hand, we recall that the Corps has responded by saying that the reservoirs were originally designed principally for navigation rather than flood control. Our observation on that is that the navigation factor is minimal while flood control is primary and always urgent. When the present operating plan and curve was agreed upon many years ago, our District participated fully in those discussions, and in the spirit of conciliation and mutual helpfulness the District agreed to the operating plan, even though the plan did not contemplate full use of the easement storage capacity in the reservoirs.

Our District must now, therefore, earnestly object to any relaxation or change in the operating plan which would work to the benefit of the reservoir shore owners and against the owners within the Drainage District. Be assured, however, that we are always mindful of the needs and concerns of our shore owner neighbors to the north. Please include us in all discussions of reservoir operations as they bear upon flood dangers in the Aitkin area.

Sincerely,

Byron Schlagel Jr.

Byron Schlagel, Jr.,
President

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION V
230 SOUTH DEARBORN ST
CHICAGO, ILLINOIS 60604

7 MAR 1980

REPLY TO ATTENTION OF

Colonel William W. Badger
District Engineer
U.S. Army Engineer District, St. Paul
U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

We have reviewed the Stage 2 Summary Report for the Mississippi River Headwaters Lakes Study. The summary report has provided us with an overview of the problems and possible solutions to the problems identified in the headwaters lakes region of the Mississippi River. We have no specific comments on the Stage 2 Report; however, the following comments are offered for your consideration during the Stage 3 study.

Since the number of actions to be considered in Stage 3 will be reduced to an analysis of the headwaters lakes operating plans, we recommend that detailed studies be conducted to quantify, to the greatest extent possible, the effects of the alternative operating plans on water quality and fish and wildlife resources. For example, during development of the different operating plans, the amount of aquatic habitat lost or created during different times of the year should be quantified. If, under a specific operating plan, aquatic habitat essential for fish spawning is lost during the breeding season, an estimate of the potential losses to the fishery should be made and the associated cost should be factored into the benefit/cost ratio for that operating alternative. An assessment of potential changes in water quality within and downstream of the headwaters lakes under each alternative should also be made. Any adverse effects on water quality should be factored into the benefit/cost ratio as well.

The Stage 3 study should also address how the different operating alternatives will interact with other management strategies on the Mississippi River. At present, a land treatment alternative and several mechanical/chemical alternatives for an upgraded and expanded sewage treatment facility at Bemidji, Minnesota will be reviewed in an EIS being prepared by the EPA. If the land treatment alternative is selected as the preferred alternative, the effect on operating plans of the reduction of approximately 1.5 MGD from the existing point source should be evaluated. Lake operating plans should be evaluated in the context of the Great River Environmental Action Team (GREAT) Studies, the development of the Upper Mississippi River Master Management Plan, and what effect each plan may have on the other water resources problems identified in the Stage 2 study, but not recommended for study in Stage 3.

We appreciate the opportunity to review the Stage 2 Summary Report. Please contact Mr. James Hooper of my staff at FTS 353-2307 concerning these comments or if there is any need to coordinate with us during your development of the Stage 3 studies.

Sincerely yours,

Ronald L. Mustard

Ronald L. Mustard, Director
Office of Environmental Review

Mar. 16,1980

Commissioner Alexander
Dept. of Natural Resources
St. Paul, Mn. 55155

RECEIVED
MAR 19 1980
COMMISSIONER'S OFFICE

Dear Commissioner,

For some number of months we have had a request from an association made up of land owners from the Black Bear - Miller Lake area in Crow Wing County to be sponsors for a dam project to suppress flood waters from the Mississippi River inundating their homes and property. The Army Corps of Engineers have offered to install the dam at no expense to them but they insist that a sponsor is necessary before they will start any construction.

As there will be some expense in the maintainance of this dam we have not made any committments until we know what legal rights or action we must take to commit the landowners to that future expense. I have personally made several contacts with both the county auditor and the assessor and have suggested to the association members that this is the department they should contact but one of their members from St. Paul has made several inquiries through your department and has been advised to have us follow up with the DNR.

Any and all information you can furnish me regarding our priorities on remaining neutral in the matter will be much appreciated. Urgency has become necessary as the Corps of Engineers have set a deadline for said construction. May I hear from you at your earliest convenience.

Sincerely yours,

John W. Erickson

John W. Erickson, Chairman
Wolford Township

E-55

Star Rt. 3, Crosby, Mn. 56441

Cat. Rad. 7

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

OFFICE OF THE
COMMISSIONER
(612) 296 2549

March 31, 1980

Mr. John W. Erickson, Chairman
Wolford Township Board
Star Route 3
Crosby, Minnesota 56441

Dear Mr. Erickson:

In reply to your letter of March 16, 1980, regarding the proposed dam project involving the Black Bear-Miller Lake area in Crow Wing County, the following information is furnished for your consideration.

The proposed project site is located on state trust fund lands which means that if the project is sponsored by a local government unit, the trust fund would have to be reimbursed in order to provide for the acquisition of property rights by the local sponsor. If the acquisition was by easement, the local sponsor would be required to provide 90 percent of the assessed valuation of the lands involved in order to reimburse the state trust fund. If the acquisition would be by fee title, it would require payment of the total assessed value of the lands involved to reimburse the trust fund.

The U.S. Corps of Engineers has indicated that the Federal Government could pay 100 percent of the estimated $95,600 first cost construction if the project is constructed under small project authority, Section 205 of the 1948 Flood Control Act, as amended.

The local sponsor must be fully authorized under state laws to give assurances of local cooperation and must be financially capable of fulfilling all required measures of local cooperation. Wolford Township should review existing laws of the state to determine if the town has the necessary legal authority.

Mr. John W. Erickson
Page 2
March 31, 1980

Federal law requires that the local sponsor must provide:

1. All lands, easements, rights-of-way, utility relocations and alterations, and highway or highway bridge construction and alterations necessary for project construction.

2. Hold and save the U.S. free from damage due to construction work.

3. Maintain and operate the project after completion without cost to the U.S.

4. Assume full responsibility for all project costs in excess of the Federal cost limitation.

5. Prevent future encroachment which might interfere with proper functions of the project for flood control.

6. Provide a contribution toward construction costs where special local benefits will accrue.

7. Provide a cash contribution for project costs assigned to project features other than flood control.

The U.S. Corps of Engineers' estimate of the annual operation and maintenance is $800.00 per year as provided by the Corps at a June 15, 1979 meeting in Crosby, Minnesota.

It is suggested that Wolford Township carefully review the [illegible] requirements and if the Township determines it has the legal authority and the financial capability to [illegible] the liability for the project, the DNR will be pleased to work with the township and the Corps of Engineers in further discussions on the project.

If you have any further questions regarding this matter, please feel free to contact Gene Hollenstein, Chief Hydrologist of the Division of Waters, Space Center Building, 444 Lafayette Road, St. Paul, Minnesota 55105, phone (612) 296-0436.

Yours truly,

Joseph N. Alexander
Commissioner

cc: Senator Rued
Representative Marlin B. Nelsen
Colonel Badger
Larry Seymour
Dave Hills

ALFRED PEMBERTON, SECRETARY TREASURER
JAMES MICHAUD, DISTRICT I REPRESENTATIVE

HARTLEY WHITE, CHAIRMAN
ROGER T. AITKEN, EXECUTIVE DIRECTOR
CAP PROGRAMS

NADINE CHASE, DISTRICT II REPRESENTATIVE
CHARLES RAISCH, DISTRICT III REPRESENTATIVE

LEECH LAKE RESERVATION
BUSINESS COMMITTEE

BOX 308 • CASS LAKE, MINNESOTA 56633
218-335-2207

June 26, 1980

Col. Wm. W. Badger, District Engineer
Department of the Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, MN 55101

Dear Col. Badger:

Reference is made to the letter of April 30, 1980 from Mr. Kowalski regarding the Mississippi Headwaters Lakes Study. We have spent a good deal of time and energy attempting to work within the framework of this study to see that no further damage is done to our tribal homeland by these dams. Apparently our efforts have been in vain, since the Corps of Engineers has taken little notice of the Leech Lake Reservation in its study.

The inherent quasi-sovereign status of Indian tribes is a matter which lay dormant for many years while others handled our affairs for us. The Corps of Engineers is not the only entity which has been slow to recognize the existence and viability of our unique legal status.

There are three major points of which the Corps should be cognizant:

1) The United States is the legal trustee of the Indian tribal estate.

2) The legal nature of any trust relationship is characterized by the principle that the administrator of a trust (the fiduciary) must, in discharging his duties, subjugate his own interests to those of the beneficiary. The conduct of the executive branch in dealing with the Indian trust estate must conform to the highest fiduciary standards. The preservation of the integrity of the trust estate must, in many cases, take precedence over the welfare of the general public, thus rendering the 'greatest good for the greatest number' theory inoperative when viewed in the context of the federal-Indian trust relationship.

3) The trust estate of the Leech Lake Band of Chippewa Indians is not limited to its diminished land holdings. The Band also possesses legitimate ownership interests in the fish, game, wild rice and other harvestable resources within the Reservation. In addition, although unquantified at present, the Tribe undoubtably possesses ownership interests in the water resource of the Reservation. All of these 'properties' are included in the Indian trust estate and come under the trusteeship of the United States government.

Col. Wm. W. Badger
June 26, 1980
Page Two

We realize that the general public does not readily comprehend or accept these fundamental tenets of the federal-Indian trust relationship. We are also aware of the fact that the Corps of Engineers is directed in large part by the wishes of the public. Nevertheless, it is the duty of the Corps of Engineers, as well as all other U.S. executive agencies, to perform within a framework which accords all due consideration to the federal government's obligations as trustee of the Indian tribal estate. The fact that this duty has commonly been neglected in the past provides no justification for continued neglect in the present.

A little history may be in order at this point to provide perspective to the issues surrounding the headwaters dams. Leech Lake and Winnibigoshish Dams are both located within the Leech Lake Indian Reservation and, therefore, the involvement of our tribal leaders with these dams goes back to their very beginnings, 100 years ago. Our leaders vigorously and vocally opposed the construction of these dams at that time. In spite of our protests, the Congress of the United States, which is the only body vested with the authority to undertake actions which are contrary to the Indians' best interests, proceeded to authorize the project.

The ensuing damages were severe and the question of compensation for these damages was to complicate affairs between the Leech Lake Band of Chippewa and the U.S. government for a number of years. Originally, the government agreed to pay a large, though inadequate sum of money annually in perpetuity. However, Congress failed to appropriate funds for this purpose. The matter was 'settled' some years later when a hand-picked group of 'friendlies' accepted a lump sum payment. Although our lands have completed their adaptation to the altered conditions, the feelings of our people remain unchanged toward this intrusion of the United States government upon our homeland.

The authorized purpose of these dams was to aid in navigation on the Upper Mississippi River. Many years ago, additional structures were built downstream which rendered the headwaters dams useless for their intended purpose. In the 1940's, general purpose legislation, such as the Flood Control Act of 1944 (P.L. 78-534), was applied to the operation of the headwaters dams, bolstering slightly the marginal justification for their existence.

All in all, it must be agreed that the operation of these dams has proven to be little more than an on-going expense to the U.S. taxpayer. As superfluous as these dams are, it would clearly be unfeasible to discontinue operation or to demolish them due to the negative environmental impacts which would surely ensue.

now, still searching for a mission, the Corps of Engineers has empted its recently de-funded 'Mississippi Headwaters Lakes Study'. s study has been investigating the potential for using these waters purposes which are not presently authorized by Congress.

our part, we feel that we have erred by attempting to participate this study. It has proven to be a most sorry vehicle for the assert- of our rights and the protection of our trust estate. We will gorously oppose, in the federal courts if necessary, the introduction any new function for these dams which presents a potential threat to trust estate.

e government of the Leech Lake Indian Reservation feels very strong- that this study should be permanently and finally terminated at this int. We further feel that authorization should be revoked for the eration of dams within our Reservation to aid in navigation and flood ntrol, for which they are of negligible utility.

r feeling is that the highest and best use of these dams, the only fensible purpose for them, is to conserve and enhance the magnif- ant headwaters environment which they devastated a century ago. doing this the U.S. government would rectify a past wrong and uly fulfill its trust obligations to the Chippewa Indians of the ech Lake Reservation.

ese comments will be processed through appropriate federal channels r further comment. We trust that you will give this matter care- consideration and we welcome any comments which you may have.

Sincerely,

Hartley White

Hartley White, Chairman
LEECH LAKE INDIAN RESERVATION

:mi

[illegible]

14 July 1980

Mr. Hartley White
Chairman
Leech Lake Reservation Business Committee
Box 308
Cass Lake, Minnesota 56633

Dear Mr. White:

This is in response to your 26 June 1980 letter commenting on our Mississippi River Headwaters study.

We appreciate receiving your candid comments concerning the Leech Lake Reservation's position on the regulation of the six Mississippi River Headwaters Lakes. Your comments of course are most specifically related to Winnibigoshish and Leech Lakes, which lie within the Leech Lake Reservation boundary. We believe we should elaborate on these same issues as they relate to the Corps of Engineers. The following comments are provided to serve this purpose.

The Corps mandate for development and regulating the six Mississippi River Headwaters Lakes and for conducting the current Mississippi River Headwaters study derives from congressional acts. Congress authorized construction of the headwaters lakes dams by the 14 June 1880 and 2 August 1882 Rivers and Harbors Acts and, in 1888, directed the Secretary of War to establish regulations governing control of water levels and discharges. The authority for the present Mississippi River Headwaters study is contained in a 7 June 1945 resolution by the Committee on Rivers and Harbors of the House of Representatives. The resolution reads:

> Resolved by the Committee of Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Mississippi River above Coon Rapids Dam near Minneapolis, Minnesota, submitted in House Document Numbered 66, Seventy-third Congress, first session, and previous reports, with a view to determining if any modifications of previous recommendations with respect to navigation, flood control, and other purposes are advisable at this time, including consideration of the operation of the existing headwaters reservoirs in order to obtain the greatest possible benefits to all affected interests.

NCSED-PB 14 July 1980
Mr. Hartley White

Specific study efforts in response to the 1945 resolution have been sporadic and have usually addressed special problem areas such as a possible dam to control White Oak Lake (near Days High Landing) and evaluating hydrologic relationships between Pokegama and Sandy Lakes and the Mississippi River at the city of Aitkin, Minnesota. Studies were generally limited by available funding under the 1945 authority.

The current study effort received funding in fiscal year 1976 and in each subsequent year to date. The study proceeded from an initial public meeting held in Grand Rapids, Minnesota, on 15 December 1976 and from a plan of study published in January 1977 (stage 1 report). Preliminary study results were documented in a draft preliminary stage 2 report, dated February 1978, and in a second stage 2 report dated September 1979. All three reports were circulated for review and comment, but only the September 1979 report contained preliminary study results of the lake regulating plan evaluations.

The headwaters study is now in stage 3. This stage of study will allow expansion of the work discussed in the stage 1 and 2 reports and evaluation of additional regulating plans such as a "conservation plan" involving Leech Lake, as discussed in the 15 and 16 January 1980 tribal and Bureau of Indian Affairs letters commenting on our stage 2 report.

Unfortunately, manpower constraints have not allowed us to continue detailed hydraulic work on the study or to make the corrections needed to improve computer program performance. As a result, no additional regulating plans have been evaluated since preparation of the September 1979 report, and study progress has been limited. Contact has been maintained with study participants (including the Leech Lake Tribe), and the principal 1980 study work effort has focused on developing a drought plan of action for the cities of St. Paul and Minneapolis. This plan of action emphasizes water conservation practices such as alternate supply sources, sprinkling bans, and reduction of water losses and consumption. Additional study effort will depend on future funding and available manpower constraints.

We agree that the study has not been comprehensive enough and, specifically, has not developed the conservation plan evaluation requested by the tribe. The September 1979 report was simply a summary of work done to date on the four operating plans that were to be used as a frame of reference for futher evaluation. We also agree that the Mississippi River Headwaters study has not been a vehicle for asserting Indian rights. The matter of Indian rights falls under the jurisdiction of Congress and the Federal Courts, and our study deals only with the costs and benefits of possible water resource alternatives.

In the matter of lake regulation, the Corps of Engineers is directed by Department of Army regulations (formerly the War Department) that were authorized by Congress. These regulations are broad and provide the District Engineer with considerable flexibility in control of the Mississippi River Headwaters Lakes. In keeping with this flexibility, the Corps of Engineers has regulated the six headwaters lakes to accommodate public (including Leech Lake Tribe) interests within the lake flowage rights purchased in the 1880's.

14 July 1980

[illegible]

[illegible] responsibility of the St. Paul District to [illegible] plans for the headwaters reservoirs. The Corps of [illegible] District, have not been asked to review or determine [illegible] of water rights held by the Chippewa Tribe. Although you persuasively [illegible] the Tribe's case regarding water rights, the St. Paul District offers no [illegible] in this matter.

[illegible] that our office has not ignored the voice of the Leech Lake [illegible] representatives have met with tribal officials to discuss study [illegible] number of times during the course of the study. The [illegible] our [illegible] April 1980 letter to the Reservation Business Committee [illegible] continuing interest in tribal concerns for operation of Leech [illegible] would like to assure you that, even if the Mississippi River Headwaters [illegible] discontinued, your 26 June 1980 letter will be included in the terminated [illegible] as a guide for any future work involving headwaters lakes regulation.

[illegible] Mr. [illegible] Loftus and Mr. Ed Fairbanks [illegible] on a time and format for a Leech Lake [illegible] understand from recent telephone conversations with [illegible] between members of the Leech Lake Tribal Board and [illegible] the Corps of Engineers is desirable. Study manager [illegible] will contact your office to arrange a convenient date [illegible].

Sincerely,

WILLIAM W. BADGER
Colonel, Corps of Engineers
District Engineer

ALFRED PEMBERTON, SECRETARY TREASURER
JAMES MICHAUD, DISTRICT I REPRESENTATIVE

HARTLEY WHITE, CHAIRMAN
ROGER T. AITKEN, EXECUTIVE DIRECTOR
CAP PROGRAMS

NADINE CHASE, DISTRICT II REPRESENTATIVE
DANIEL BROWN, DISTRICT III REPRESENTATIVE

LEECH LAKE RESERVATION
BUSINESS COMMITTEE

BOX 308 • CASS LAKE, MINNESOTA 56633
218-335-2207

September 24, 1980

Dept of the Army
St. Paul District
Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

ATTN: Lt. Col. Stephen Draper

Dear Colonel Draper:

This is to summarize our understanding of the topics which were discussed at the 17 September 1980 meeting between yourself, members of your staff, and Leech Lake Reservation representatives Ed Fairbanks and John Loftus.

Major points of discussion included the following:

1.) Control of Lake Levels: Water levels in the Mississippi Headwaters Reservoirs are presently subject to change through the joint authorization of the District Engineer and the Governor of Minnesota. The Tribe is of the opinion that the present system fails to address its vested rights in the waters and related resources of the Mississippi River and does not provide a framework within which the federal government can adequately discharge its duties as guardian of the Indian trust estate. In order to rectify this situation, it was proposed that the possibility of a tri-agency agreement be explored, the three parties being the Corps of Engineers, the State of Minnesota and either the Tribe itself or the Secretary of the Interior. It was agreed upon by both parties present at the 17 September meeting that this concept merits further study.

2.) The Mississippi Headwaters Lakes Study: The purpose of this study is to develop an operating plan for the Headwaters Reservoirs which will optimize the benefits derived from their operation and minimize costs and damages. At its present stage, the study has basically narrowed the field to two alternatives: The present operating plan and one which would provide supplemental flow to the Twin Cities area. The Tribe is of the opinion that the methods employed and the factors considered to date in assessing costs and benefits have not been comprehensive enough and are subject to considerable manipulation. Further, the Tribe feels that the viability of the traditional Cost/benefit ratio method of decision making must be re-evaluated in light of the fact that an inherent conflict of interest may exist with regard to the federal government's responsibilities to the Indian trust estate.

It was agreed that additional studies would be necessary in order to evaluate the effects of various operating plans on the trust estate of the Leech Lake Band of Chippewa. Also discussed was the desire of the Tribe to see the Corps of Engineers develop an additional alternate plan, which has been referred to as the 'Conservation Plan'. This plan would be geared toward optimizing the production of natural resources which are native to the Headwaters Lakes, the Mississippi River and adjacent areas.

The necessary studies would include, but not be limited to, analyses of the effects of various flow regimes on the following:

a) the annual yield of wild rice;

b) fish habitat and propagation areas;

c) habitat of fur-bearing animals and waterfowl;

d) cranberry bogs and other related resources;

e) the economic impacts of all of the above on the Leech Lake Band of Chippewa.

Both parties to the 17 September meeting expressed qualified support for the foregoing concept and agreed to proceed with further investagation of the matter.

3.) The Tribal representatives recommended that an Indian Liaison position be established at the St. Paul District Office in order to ensure continuity in the relationship between the Corps of Engineers and the federally-recognized Indian tribes within the District. The Corps of Engineers will take this matter under advisement.

4.) The possibility of the Corps of Engineers working with Indian youth through career presentations at local schools, the development of summer internship programs and similar efforts was discussed. Such projects are well within the scope of the Corps of Engineers' functions and it was agreed that planning for such programs should commence as soon as possible.

The above constitutes our recollection of what was, in our opinion, a most meaningful dialogue. If you feel that the substance of the discussion is not adequately reflected in this memo, please do not hesitate to contact us. We hope that through our common efforts we will be able to establish the viable government-to-government relationship which has been lacking in the past and is so vital to the future.

Sincerely,

Hartley White

Hartley White, Chairman
LEECH LAKE INDIAN RESERVATION

CC: R.W. Mayotte, Supt., MN Agency, BIA

[illegible]-PB 5 December 1980

Mr. Hartley White
Chairman
Leech Lake Reservation Business Committee
Box 3[illegible]
Cass Lake, Minnesota 56633

Dear Mr. White:

Your 24 September 1980 letter summarized the points of discussion at our recent meeting quite well. However, I wish to respond to your points to insure that both of us are in agreement as to our respective positions. In addition, I would like to summarize our understanding of meetings held between individuals from your organization and individuals from our office since that time.

First, in regard to your 24 September letter, the following clarifications are in order. In your discussion of "control of lake levels," the State of Minnesota's role in operation of the six headwaters lakes may be overstated. Minnesota Statutes 110.47 to 110.52 appear to give the State and the Corps of Engineers joint operating power in regard to the headwaters lakes. However, Congress has given the Corps sole authority to operate these lakes. No cooperative agreement exists between the Commissioner of the Department of Natural Resources and the Corps for joint Federal and State control of the lakes. In actual practice, the Corps does give a great deal of consideration to the State's recommendations concerning the headwaters lakes operation. For example, the Commissioner of the Department of Natural Resources speaks for the State of Minnesota as a protector of fish and wildlife and other environmental concerns. Present lake operating plans closely approximate operating limits and flows recommended by Minnesota. This is particularly true in regard to minimum flow releases to sustain downstream fisheries and other wildlife habitat.

Similarly, a request from the Governor of Minnesota for low flow releases from the six headwaters lakes during drought conditions would be considered by the Corps. The request might not be implemented, depending on several factors which include: possible adverse effects on the six lakes, the Leech Lake Tribe, and the lake residents; the amount of flow requested; other conservation measures available to downstream interests; possible length of drought; and the seriousness of the situation. Any decision by the Corps to make special low flow releases during drought conditions would follow a meeting of all concerned interests.

NCSPD-PB
Mr. Hartley White

5 December 1980

In response to your second paragraph on the Mississippi River Headwaters Lakes study, I think some discussion is necessary. First, with regard to your statement that the assessment of costs and benefits is subject to considerable manipulation, let me assure you that our economic analysis is performed using guidelines recommended by the U.S. Water Resources Council and incorporates widely accepted methods of benefit analysis. Because the summary data is the only portion of the analysis published, it may seem to an outside observer that the economic analysis is a "black box." All results are, however, explained in greater detail in our working papers.

You also mentioned in that paragraph that the Tribe does not feel it is appropriate to use the benefit-cost ratio in decision-making. The benefit-cost ratio concept has been, and continues to be, the primary means for us to determine which alternatives provide the best use of Federal dollars. The Headwaters Lakes Study is now at that stage. However, when we reach the stage where the District Engineer is prepared to make a recommendation to send forward to Congress, that recommendation must take into account a number of other impacts. To weigh these impacts, we perform a number of specific analyses, including a National Economic Development analysis, a Regional Development analysis, an Environmental Quality Assessment of all the alternatives, and an analysis of other social effects. When we are ready to complete our report and our recommendations, we circulate our proposed draft to a number of people and agencies so they have an opportunity to comment. Their views are incorporated in our final recommendations. Ultimately, of course, Congress makes the final decisions. The point of this dicussion is to assure you that the benefit-cost ratio will not be the sole consideration in our recommendations on the Mississippi Headwaters Lakes Study.

You also indicated in item 2 that additional studies were necessary to determine the economic data base for the Leech Lake Band. I believe that during the 10 September meeting and at later meetings we agreed that we would pursue a joint venture between the Corps of Engineers and the Leech Lake Band to develop that data. That still stands in our minds, and our economist has been in touch with the appropriate people working for your committee to develop a methodology to get the data base we need.

Your item 3 reiterates your recommendation that an Indian liaison position be established at the St. Paul District Office. That position has been established in the North Central Division, our next higher headquarters. We have been in contact with the individual designated as the Indian Liaison Officer to establish the scope and parameters within which such an Indian Liaison Officer should work in this District. When we received the response, which should be soon, we shall take the necessary action to establish formal liaison communications between your committee and this District.

[illegible]
Mr. Hartley White

5 December 19[illegible]

In regard to our discussion about this District becoming involved in working with the Indian schools at Leech Lake through career presentations and special employment programs, as mentioned in your fourth item, we would be most eager to begin planning these programs with you. I have asked Ms. Sharon Brown, our Equal Employment Opportunity Officer, to contact you by telephone before 15 December so that the two of you can set a date for her to visit with you and make the necessary arrangements. Her telephone number is (612) 725-7431.

The meeting we held with members of the committee on 25 and 26 September can be summarized very simply. When we arrived, we provided your representative with copies of the type of economic information that we need to include in our study. During our visit, we reiterated the fact that we will conduct a joint program of data collection to insure that the Leech Lake Indian Tribe's concerns are adequately addressed in our study. We noted that, in most planning efforts, economic data are readily available from the communities involved and we do not get involved in [illegible] data collection. However, we agreed that the Leech Lake Reservation situation was a special case and that a joint program of economic data development was necessary to insure that we were, in fact, considering all facets of the "public interest." Since that meeting, our economist involved in this study, Ms. Jody Rooney, has been in contact with her counterparts from the Reservation Business Committee and, I believe, the program is slowly but adequately being formulated.

I believe all of our meetings to date have been very productive, and I appreciate the hospitality your committee showed on 25 and 26 September. I look forward to future meetings and to continued good communications between the Leech Lake Band and the St. Paul District.

Sincerely,

[illegible]
Lieutenant Colonel, CE
Deputy District Engineer

IN REPLY REFER TO:

United States Department of the Interior

NATIONAL PARK SERVICE
MIDWEST REGION
1709 JACKSON STREET
OMAHA, NEBRASKA 68102

JAN 2C 1981

In accordance with President Carter's August 1979 Environmental Message to Congress, the National Park Service has completed its Conceptual Master Plan for the Upper Mississippi River in Minnesota. The plan proposes National Wild and Scenic River designation with Federal administration of 221-river miles and State administration of 68-river miles.

During the planning process, a group of eight counties along the study reach of the river formed the Mississippi Headwaters Board. The Board independently prepared a plan for management of the river based on local and State government powers. The Department of the Interior has recommended that the National Park Service plan be held in abeyance to allow the Mississippi Headwaters Board an opportunity to prove the feasibility of the local plan.

Enclosed you will find a copy of the Transmittal Report for the Upper Mississippi Conceptual Master Plan. The report details the recommendations of the Department and provides descriptions of the events and the correspondence that led to the final recommendations. The report also contains summaries of both the National Park Service plan and the Mississippi Headwaters Board plan. A summary of the record of public meetings held in December 1980 to discuss the Park Service plan is included in the Transmittal Report.

The Transmittal Report is being provided for your information and reference. Questions concerning the Upper Mississippi River Conceptual Master Plan should be directed to Mr. Bill Farrand, Rivers and Trails Coordinator, Midwest Region, National Park Service, 402-221-3482 or FTS 864-3482.

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
BOX 32, CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

DNR INFORMATION
(612) 296-6157

FILE NO.________

March 25, 1981

The Honorable Donald Fraser
Mayor of Minneapolis
City Hall
Minneapolis, MN 55415

Dear Mayor Fraser:

MUNICIPAL WATER SUPPLY FROM THE MISSISSIPPI RIVER

In the drought year of 1976, considerable concern was expressed to the Governor's Office, the Corps of Engineers, and this Department by Minneapolis public works officials with respect to the receding flow rate of the Mississippi River as near critical conditions were contemplated. The matter was of considerable public concern as it was reported that Minneapolis had only one day's worth of water storage capability at the time.

Regretably, but predictably, we are again faced with declining river flow rates which are following the same recession curve observed in 1976. At this point, no one knows or can predict the minimal flow rate that will be experienced. It is prudent, however, to consider what options are available to the City should water supply conditions deteriorate to more critical levels than were experienced in 1976, perhaps approaching the record low flows experienced in the drought of the 1930's.

It would also be pertinent to outline the provisions of Minnesota Statutes 1980 § 105.418, which reads as follows:

> 105.418 CONSERVATION OF PUBLIC WATER SUPPLIES
>
> During periods of critical water deficiency as determined by the governor and declared by order of the governor, public water supply authorities appropriating water shall adopt and enforce restrictions consistent with rules adopted by the commissioner of natural resources within their areas of jurisdiction to restrict lawn sprinkling, car washing, golf course and park irrigation, and other non-essential uses, together with appropriate penalties for failure to comply with the restrictions. The commissioner may adopt emergency rules pursuant to section 15.0412, subdivision 5 relating to matters covered by this section during the year 1977. Disregard of critical water deficiency orders, even though total appropriation remains less than that permitted, shall be adequate grounds for immediate modification of any public water supply authority's appropriator's permit.

Mayor Donald Fraser
Page 2
March 25, 1981

In addition, statewide rules governing Appropriations of Waters have been promulgated effective August 4, 1980. A copy of these rules are enclosed. You will be particularly interested in 6 MCAR § 1.5053 D.1.g. (page 15) and § 1.5057 B. (page 28).

We feel that the first means to consider for alleviation of water shortage during a drought is conservation. The City of Minneapolis should develop a contingency plan for short term emergency conservation of water supplies during droughts. This should include but not be limited to a survey of large water users and an evaluation of methods to reduce water use during a drought. Also a conservation plan for long term moderation of the municipal water use should also be developed along with a public information program to increase the awareness for the need to conserve.

However even with effective conservation practices the impact on Minneapolis municipal supplies resulting from emergencies other than low flow such as break down in intake pumps or contamination of the Mississippi River preventing its use is important. Therefore, Minneapolis should seriously consider developing an auxiliary water supply from other sources such as ground water in order to eliminate total dependence on a single source, increase reserve capacity and reduce the demand on the Mississippi River during severe droughts.

In a related matter we are in the process of reviewing the City of Minneapolis' water appropriation permit number 78-6216 issued August 1, 1978. The newly promulgated rules require public water supply authorities to submit more extensive information than originally required. Permit 78-6216 authorizes appropriation of water from the Mississippi River at a rate not to exceed 240,000 gallons per minute or 125,000 million gallons a year in accordance with the application filed at that time.

The water use reported by the City of Minneapolis corresponds to an appropriation rate of [illegible]1,760 gallons per minute or approximately 22,13[illegible] million gallons per year. Since this is considerably lower than the previous request, clarification should be supplied as to the City's actual water needs.

This information, and the following, will be utilized in review and probable amendment of the City's water appropriation permit:

1. The number of domestic users.

2. Reasonable projection of population growth.

3. The number and type of industrial and commercial users of the public water supply system.

4. The amount of water to be supplied to domestic, industrial and commercial users respectively.

Mayor Donald Fraser
Page 3
March 25, 1981

5. Other users by type of use and amount to be used from the public water supply system such as:

    a. golf courses
    b. recreational lake level maintenance
    c. water transferred to other supply systems

6. Information regarding the quantity of the appropriated water to be used in distribution and waste water treatment facilities, not including volume of actual waste water.

Our objective is of course to provide for a more reasonable and justifiable allocation of the waters available from the Mississippi, and to assist the City of Minneapolis in planning for those unfortunate but inevitable periods of water deficiency. A policy of assuming that involved state and federal officials can or will respond to such situations by immediate releases of additional water from the upstream lakes is unrealistic, based not only on hydrologic considerations such as travel time in the river but also third-party impacts on lakeshore and riverside interests above the City of Minneapolis.

I hope you and the City staff will feel free to consult with Larry Seymour, Director of our Waters Division, and Hedia Rieke of the Division staff about this important matter.

Yours truly,

Joseph N. Alexander
Commissioner

Enclosure

cc: Colonel Badger
Gary Botzek
Perry D. Smith
Larry Seymour

United States Department of the Interior

FISH AND WILDLIFE SERVICE
St. Paul Field Office, Ecological Services
570 Nalpak Building
333 Sibley Street
St. Paul, Minnesota 55101

IN REPLY REFER TO:

May 27, 1982

Colonel William W. Badger
District Engineer, St. Paul District
U.S. Army Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

The U.S. Fish and Wildlife Service has reviewed the draft Stage 3 Summary Report on the Mississippi River Headwaters Lakes Study.

Based on the information presented in the report, we support the conclusion that the present operating plan for the Headwaters Lakes should be retained (alternative 1). This would allow for some changes under the conservation plan (alternative 9) which are within the limits of the current operating plan. The fish and wildlife resources of the area are well adapted to current conditions, and there seems to be a balance between the various concerns.

These comments have been prepared under the authority of and in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and are part of our continuing coordination with the Corps on this project.

Sincerely,

Richard F. Berry

Richard F. Berry
Field Office Supervisor

Minnesota Pollution Control Agency

[illegible] 30, 1982

[illegible] G. Rapp, Colonel
[illegible] Corps of Engineers, District Engineer
[illegible] U. S. Post Office & Customhouse
[illegible] Paul, Minnesota 55101

[illegible] Colonel Rapp:

[illegible] you for your August 17, 1982 letter concerning the draft [illegible] report for the six Mississippi River Headwater [illegible].

[illegible] indicated in your letter, the draft feasibility report does [illegible] recommend major changes in the present operating plan for [illegible] headwater lakes, and therefore our Agency's comments are [illegible] limited at this time. It is noted that some of the [illegible] lakes perimeter dikes will be upgraded as part of the [illegible] scheduled maintenance program. On page 162 of the [illegible] it is recommended that environmental assessments be [illegible] prior to the upgrading of these dikes. The [illegible] should carefully evaluate various alternatives as [illegible] relate to environmental degradation so that the least [illegible] method of dike upgrading can be identified.

[illegible] contact me if you need additional information.

[illegible],

[illegible] Breimhurst
[illegible] Director

Phone ___296-7301
[illegible] West County Road B2 Roseville Minnesota 55113-2785
[illegible] Duluth Brainerd Detroit Lakes Marshall Rochester
[illegible]

NSP

Northern States Power Company

[illegible]
Minneapolis, Minnesota [illegible]
Telephone [illegible]

August 31, 1982

Mr Carl Stephan
St Paul District, Corps of Engineers
[illegible] US Post Office & Custom House
St Paul, MN [illegible]

Dear Carl:

We have reviewed a copy of E G Rapp's letter listing the recommendations to the Mississippi River Headwaters Study Draft Report. We are surprised at the first recommendation which indicates that the present operating plan for the headwaters lakes should be retained.

Based on results from the Computer Operations Study of Reservoir Operations for Six Mississippi River Headwaters Dams, several low flow plans appear very feasible. We believe that the *1600 cfs minimum flow* at Anoka plan is a viable solution to several twin-cities area water needs, and should receive strong consideration. According to the Corps of Engineers analysis, economic benefits from this low flow plan are very high. The average annual negative impacts resulting from this plan are low including fisheries, wildlife, recreation and wildrice production.

It appears that effects of implementing the 1600 cfs minimum flow plan on reservoir and lake property owners and recreators would be negligible, while benefits to downstream water appropriators would be substantial. Instituting the 1600 cfs low flow plan is a very logical solution to provide the water [illegible] needs for the twin cities area and does not interfere with headwater reservoir activities. Therefore, we urge that the 1600 cfs minimum flow plan be adopted, and we would strongly support any effort to implement it.

[illegible] Bechthold, Manager
Regulatory Compliance and Services

[illegible]

cc: [illegible] D Heberling

CORPS RESPONSE TO 31 AUGUST 1982 LETTER FROM NSP

Generally speaking, these comments are correct (see the summary section on page 185 of the main report). However, as also stated on that page, the environmental, social, and political consequences of adopting the 1,600-cfs low flow plan as a permanent procedure would offset the identified economic advantages. A summary evaluation of the alternative plans on pages 97 to 110 of the main report supports the final recommendations, which are to retain the present operating plan (plan 1) and incorpotate a variation of the conservation plan (plan 9), which is within the limits of the present operating plan. The report further recommends that the 1,600-cfs low flow plan (plan 2) could be used in an emergency, but that the cities of Minneapolis and St. Paul should develop alternative water supply sources and conservation techniques that would not only provide a margin of safety during drought conditions but would protect the cities in the event of an unexpected water quality problem, such as from a chemical spill (see also main report, page 222).

MINNESOTA HISTORICAL SOCIETY
FOUNDED IN 1849
690 Cedar Street St. Paul Minnesota 5510

31 August 1982

Colonel William W. Badger
District Engineer/St. Paul District
Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

NCSPD-PF
RE: Draft Feasibility Report for the six Mississippi River Headwaters Lakes and the surrounding area. The six lakes are Winnibigoshish, Leech, Pokegama, Sandy, Pine, and Gull.

MHS Referral File Number: 0-940

Thank you for the opportunity to review and comment on the above project. It has been reviewed pursuant to responsibilities given the State Historic Preservation Officer by the National Historic Preservation Act of 1966 and the Procedures of the National Advisory Council of Historic Preservation (36CFR800).

This review concurs with the findings of the report regarding historic and archaeological resources. Any changes brought about by further study of individual lake operating plans should be reviewed by this office. The erosion of numerous archaeological sites along the Headwaters Lakes is a serious problem. It is hoped that the Corps operations and maintenance units will be able to adequately deal with this problem.

Again, thank you for your participation in this important effort to preserve Minnesota's heritage.

Sincerely,

Dennis A. Gimmestad

for Russell W. Fridley
State Historic Preservation Officer

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BOX 32, CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

DNR INFORMATION
(612) 296-6157

FILE NO ______________

September 7, 1982

Colonel Edward G. Rapp
District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

Attention: NCSPD-PF

Dear Colonel Rapp:

The following Department comments are provided on the draft feasibility report for the six Mississippi River Headwaters Lakes and surrounding area dated: August, 1982. We are sorry we could not provide comments by your August 31, 1982 deadline.

We look forward to receiving the final report on this study.

Sincerely,

DIVISION OF WATERS

Larry Seymour, Director

[illegible]
Attachment
cc: Dan Retka, MDNR - Grand Rapids
Dave Hills, MDNR - Brainerd
Gerry Paul, MDNR - Bemidji

AN EQUAL OPPORTUNITY EMPLOYER

Department of Natural Resources Comments

Re: Draft - Feasibility Study Mississippi River Headwaters Lakes in Minnesota, August, 1982

SYLLABUS

Although we've already contacted the Study Manager in regards to this,we feel
its appropriate to document. Page two, the recommendation for the problem area
of Black Bear and Miller Lakes flood problem is inconsistent with respect to the 1
non-availability of a local sponsor. As you know, the main report identifies
Crow Wing County as the proper local sponsor.

Page 59, Paragraph 4

We would suggest that the last sentence in this paragraph be changed to read:

"The magnitude of the problem will depend on water 2
conservation and water management planning."

Page 83, Plan 1 - Present Operating Plan

We would reaffirm our request made to the Corps of Engineers in our comments dated: January 31, 1980 that the following statement be added near the beginning of this discussion:

"The present dam operation plan has been established based on a cooperative agreement between the Department of the Army and the State of Minnesota.

The plan is in compliance with requirements of Minnesota 3
Statutes Section 110.49 which prescribes maximum and minimum
stages and resultant discharges from each reservoir."

CORPS RESPONSE TO 7 SEPTEMBER 1982 LETTER FROM MDNR

1. Concur. The report has been corrected.

2. The report has been changed.

3. No signed cooperative agreement exists between the Corps and the State of Minnesota. A draft agreement was prepared at one time, but was not completed when it was determined that the Corps could not sign such an agreement. However, the Corps of Engineers attempts to follow State of Minnesota regulations, and low-flow schedules for the six Mississippi River Headwaters Lakes are basically the same as those required by Minnesota Statutes Section 110.49.

PROGRESS REPORTS

The following progress reports were mailed to over 800 people and agencies throughout the study. This method of communication was essential because of the large study area and diverse interests requiring information on study progress.

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

NOVEMBER 1981

PROGRESS REPORT

This is the eighth progress report on the "Mississippi River Headwaters Lakes in Minnesota" study. The last progress report was distributed in February 1980.

CURRENT STATUS

This three-step study is in the final stage of completion. A draft report and environmental impact statement are scheduled for completion in February 1982, with a final report and EIS scheduled for September 1982.

The Stage 2 report was completed in 1979, and this report recommended further study of 10 possible lake operating plans. Nine other water related problems were eliminated from the study at that time.

No funds were received for the study in fiscal year 1981 because of budget cuts, and no public meetings or workshops were held. However, some fiscal year carry-over funds were used to let a computer model contract in June 1981. The contract will allow redevelopment of a computer model to evaluate the 10 lake operating plans. The proposed model will replace an earlier version which was unable to handle low flow operation properly. The computer contract is scheduled for completion in January 198[illegible].

MEETINGS

The following is a summary of meetings held with study advisary groups and others since the last report.

Date	Participants	Topics	Location
20 March 1980	Representatives of Leech Lake Reservation Business Committee and Mississippi River Parkway Commission	September 1979 Stage 2 Report	St. Paul
9-10 October 1980	Tribal representatives and various Federal agents	Chippewa Tribe Business Development Conference	Grand Portage
24 November 1980	13th Annual Water Resources Seminar	Presentation of paper "Competing Water Uses in the Twin Cities Metro Area"	University of Minnesota

12 December 1980	Leech Lake Reservation Planning Staff, Ricing Committee, Minnesota DNR	Water levels and and wild rice	Cass Lake
29 January 1981	Corps, Leech Lake Tribal Representatives, KAWE-TV	Headwaters Study	Bemidji
15 June 1981	Reservation Ricing Committee, DNR, and U of M Agronomy Dept.	Wild rice and developing a "conservation plan"	Cass Lake
8 July 1981	Leech Lake Tribal Representatives	Develop a "conservation" or wild rice plan	Cass Lake
29 October 1981	Lower Mississippi River Corps Districts Leech Lake Tribal Representatives, Minn DNR	Upper Mississippi River flow limitations	St. Paul

Black Bear and Miller Lakes Flood Problem

The homeowners on Black Bear and Miller Lakes have made progress in finding a suitable sponsor for a small flood control structure. Crow Wing County has indicated to the local people that it would be the local sponsor if the Corps builds the project. The local sponsor would (a) provide the lands, easements, and rights-of-way necessary for construction; (b) hold and save the United States free from damages due to the construction works; and (c) maintain and operate the constructed works in accordance with Army regulations.

This project will be handled further under the Corps small project authority.

Drought Action Plan

The City of St. Paul has developed a drought action or water conservation plan to cope with Mississippi River low flows. Following this plan, St. Paul could possibly reduce its reliance on Mississippi River flows by 60 percent during low flow periods. The St. Paul plan takes into account reduction in consumption, increased use of surface water facilities, and construction of several new high capacity wells.

The City of Minneapolis does not have a final drought action plan at this time. Minneapolis has conducted shallow groundwater exploration activities but has not been successful in locating a suitable supply. It is imperative that Minneapolis complete a drought action plan which would include reduction in consumption and an alternate supply source during low flow periods or in the event of possible contamination.

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

FEBRUARY 1980

PROGRESS REPORT

This is the seventh progress report on the "Mississippi River Headwaters Lakes in Minnesota" study. The last progress report was distributed in March 1979.

CURRENT STATUS

In August 1979, the University of Minnesota's St. Anthony Falls Hydraulic Laboratory completed a study and reported on "The Effects of Different Operating Plans For the Six Mississippi River Headwater Dams, Part I". The report summarizes the operating plan effects of: (1) present conditions, (2) a natural flow plan, (3) a flood control plan, and (4) a water supply plan. St. Paul District summarized the results of the laboratory's report in its September 1979 Stage 2 summary report. Copies of the report were distributed for comments to principal agencies and advisory groups associated with the study.

MEETINGS

We held several meetings with the study advisory groups and others since the last report. The meetings are summarized below.

Date	Participants	Topic	Location
7 March 1979	Aitkin Area Citizens Committee and Aitkin Conservancy District	Study progress and preliminary findings	Aitkin
15 June 1979	Local officials and concerned citizens	Black Bear-Miller Lake flood problems	Crosby
2 August 1979	Aitkin Area Citizens Committee and other interested individuals	Flood Insurance	Aitkin
21 September 1979	Mississippi Headwaters Association	Study status and Wild and Scenic River Proposal	Walker
29 October 1979	North Central Division and St. Paul District Personnel	Checkpoint or status meeting	St. Paul

Date	Participants	Topic	Location
11 December 1979	Aitkin Conservancy Board and Ryan & Ryan, Attorneys	September 1979 Stage 2 report	Aitkin
17 December 1979	Commissioner and division heads of the Minnesota Department of Natural Resources	September 1979 Stage 2 report	St. Paul
22 January 1980	Ecological Services, Minnesota Department of Natural Resources	September 1979 Stage 2 report	St. Paul
5 February 1980	University of Minnesota seminar	Study summary	Minneapolis

SEPTEMBER 1979 REPORT

The September 1979 Stage 2 report conclusions are the same as those contained in the August 1978 Progress Report with the modifications indicated in the March 1979 Progress Report. The only new item involves preliminary conclusions concerning alternative operating plans for the six Mississippi River Headwaters Lakes (Winnibigoshish, Leech, Pokegama, Sandy, Pine River, and Gull). The report is subject to revision, upon receipt of comments and additional information from affected interests.

The September 1979 report represents the second stage of a three-stage feasibility investigation. It is a final summary for all the water-related problems under investigation except for the headwater lakes operation plans. Only the headwaters lakes operation plan analysis will be continued in Stage 3. At the end of Stage 3, a final report will be prepared to summarize the complete study results for all identified problems. The following summary table compares annual high- low-water losses that would occur with each of the four plans that have been considered. This evaluation was made using a computer analysis developed by the Corps Hydrologic Engineering Center in Davis California.

Operating plan comparison - average annual high - and low-water losses

Area or location	Operating plan: Alternative 1 (present conditions)	Alternative 2 (natural conditions)	Alternative 3 (flood control)	Alternative 4 (water supply)
Headwaters lakes				
Winnibigoshish	$32,460	$97,440	$72,746	$29,867
Leech	96,085	499,368	126,445	125,096
Pokegama	68,840	55,845	65,271	68,262
Sandy	96,836	407,848	196,293	92,557
Pine River	33,425	698,303	33,338	95,580
Gull	120,140	443,343	128,155	164,855
Total headwaters lake	447,486	2,202,147	622,248	576,217
Four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy)	294,221	1,060,501	460,755	315,782
Aitkin	309,600	453,760	272,560	300,520
Aitkin plus six headwaters lakes	757,386	2,655,907	894,808	876,737
Anoka	4,488,500	6,119,500	3,631,800	1,104,100
Total	5,245,886	8,775,407	4,526,608	1,980,837

The table shows that the present operating plan is the most attractive of the four plans evaluated if only the damages at Aitkin and the six headwaters lakes are considered. The present operating plan with approximately $757,000 in average annual damages ranks first. The low-flow plan with approximately $877,000 in average annual damages is second. The high-flow plan is third, with $895,000 in average annual damages.

If the water needs at the Twin Cities (Anoka) are included, the plans are ranked differently. The low-flow plan is first with $1,981,000; the high-flow plan is second, with $4,527,000; and the present operating plan is third with $5,300,000 in average annual damages. The return to natural conditions ranks last under either set of circumstances.

FURTHER STUDY EFFORTS

Additional study efforts in 1980 will involve social and environmental studies, evaluation of additional operating plans, archeological studies, and public meetings or workshops. You will be advised of area meetings to discuss the results of the Stage 2 study report analysis. The meetings will be coordinated with the Mississippi River Headwaters Association and will be held this spring.

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

MARCH 1979

PROGRESS REPORT

This is the sixth progress report on the "Mississippi River Headwaters Lakes in Minnesota" study. The last progress report was made in August 1978.

CURRENT STATUS

The workshops originally described in our August 1978 progress report have not been held. The University of Minnesota's St. Anthony Falls Hydraulic Laboratory has experienced additional problems with the computer model that will be used to evaluate various headwaters lake operating plans. Workshops will be held this summer as soon as some operating plans are ready for review.

MEETINGS

Several meetings were held with study advisory groups and others since our last report. The meetings are summarized below.

Meeting date	Representative	Topic	Location
7 September 1978	Aitkin Conservancy District, city of Aitkin, Aitkin County.	Effects of 22-23 August 1978 rainstorm and headwaters lake operation effects.	Aitkin
14 September 1978	Leech Lake Reservation Business Committee plus several Federal and State agencies.	Study status and dredging permits.	Cass Lake
4 October 1978	Upper Mississippi River Basin Commission.	Lake Bemidji water quality.	St. Paul
18 January 1979	Aitkin area citizens committee and other interested individuals.	Flood insurance.	Aitkin

REVISED REPORT FINDINGS

Because of additional review and refinement of information contained in the February 1978 preliminary stage 2 report, some conclusions have been revised since the August 1978 progress report:

Black Bear and Miller Lakes Flood Problem

A low-head dam or levee with gated control could prevent recurring flood damage in the area, and such a structure now appears economically feasible. The first cost of the required structure is estimated at $95,600.

This project requires a local sponsor that has taxing and condemnation authority and is willing to share in the project costs. The project costs will be divided as follows: Federal - 75 percent, local - 20 percent, and State - 5 percent.

The Corps asked the Minnesota Department of Natural Resources to consider acting as local sponsor. In its 2 February 1978 response, the Department of Natural Resources indicated that "...we would prefer that local governmental units sponsor and maintain such a structure." Therefore, local interests are responsible for finding an appropriate local sponsor. Unless a local sponsor can be found, the study will be discontinued.

Whitefish Lake Channel Obstructions and Marking

Permanent connecting channels at six locations in the Whitefish Chain of Lakes are economically feasible. However, this project also requires the support of a local sponsor with taxing and condemnation authority before it can be submitted to Congress for authorization of construction. Possible local sponsors might be the county, watershed district, soil and water conservation district, or lake improvement district. Local interests are responsible for finding an appropriate project sponsor in this instance also.

Headwaters Lakes Perimeter Dikes

The 28 perimeter dikes that prevent Winnibigoshish, Pokegama, Sandy, and Pine River Lakes from overflowing onto private lands or into unauthorized outlets were surveyed and found to have adequate cross sections and elevation grades in accordance with original designs. However, each dike must now be evaluated further to see if it meets current design and safety requirements. These dikes should be scheduled for detailed inspection, testing, and upgrading, as necessary, as part of the District's regularly scheduled maintenance program and funding authority.

Leech Lake Dam Inlet Channel Restrictions

The Leech Lake inlet channel dredging proposal appears economically justified and would lessen average annual flood damages around Leech Lake. The proposal and supporting data have been transferred to the St. Paul District's Construction-Operations Branch for scheduling with operation and maintenance funds. The work will presumably be accomplished at a later date if appropriate funding and environmental concerns are satisfied. Further inquiries on the status of this proposal should be directed to Mr. Thomas Oksness (612-725-7563).

Leech Lake Marsh Channel Cutoffs

After further investigation, the development of marsh areas in the 4-mile reach below Leech Lake Dam was found not economically feasible.

The proposal to develop a subimpoundment in Leech Lake to improve fish and wildlife habitat and offset earlier environmental losses associated with channel dredging was also found not economically feasible. The Sugar Point bog area was first thought to have economic feasibility, but was ruled out after additional study. The Sugar Point bog site also included three eagle nests which, under the Endangered Species Act, would probably have precluded development of the area.

RELATED STUDIES

- In July 1978 the University of Minnesota completed a photo interpretation study of infrared imagery of Leech Lake shoreline habitat. The report, which includes 14 overlay transparencies of U.S. Geological Survey quadrangle maps, is titled "Remote Sensing Analysis of the Vegetation of the Mississippi River Headwaters - Leech Lake, Minnesota." Copies of the report have been provided to the U.S. Fish and Wildlife Service, U.S. Forest Service, Leech Lake Reservation Business Committee, and Regional Development Commission (Staples, Minnesota). The report will be particularly useful in evaluating the effects of development proposals around Leech Lake.

- Fieldwork will continue this summer on the 2-year Leech Lake fishery study. The primary purpose of this study, which is expected to be completed in the fall, is to determine the optimum range of water levels for fish production, particularly northern pike.

- All six headwaters lakes - Winnibigoshish, Leech, Pokegama, Sandy, Pine River, and Gull - will be surveyed in a 1-year water quality sampling program begun in September 1978. The work is part of a St. Paul District program to obtain basic data on all impoundments operated by the Corps. The data will be used to determine the need for future water quality sampling, identify potential and existing water problems, and help determine the need for revising present lake operations to improve water quality.

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

ST PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST PAUL, MINNESOTA 55101

AUGUST 1978

PROGRESS REPORT

This is the fifth progress report on the Mississippi River Headwaters [illegible] in Minnesota study. The last progress report was made in [illegible] [illegible].

[illegible]

[illegible] University of Minnesota's St. Anthony Falls Hydraulic [illegible] [illegible] calibrating the computer model. Evaluation [illegible] [illegible] Lake operating plans is dependent on the development [illegible] [illegible] model. It is anticipated that the model will be ready [illegible] [illegible] information on several operating plans for review at the [illegible] [illegible] scheduled in October.

[illegible] meetings were held with study advisory groups during [illegible]. [illegible] conclusions of the February 1978 draft study report [illegible] St. Paul District Office were reviewed at each of these meetings. [illegible], representation, and locations were as follows:

Date	Representative	Location
[illegible] 1978	Aitkin Conservancy District	[illegible]
March [illegible] 1978	Leech Lake Reservation Business Committee	[illegible]
[illegible] 1978	Aitkin Agricultural Interests	[illegible]
[illegible] 1978	Whitefish Lake Property Owners Association	[illegible]
[illegible] 1978	Mississippi Headwaters Association	[illegible]

FEBRUARY 1978 REPORT

The draft headwaters lakes preliminary report contained the following conclusions concerning 10 study problems:

Optimum Lake Operating Plans

Studies have not progressed far enough to make recommendations concerning alternative lake operating plans. The initial study analysis will evaluate four possible operating plans that emphasize the following: (1) natural flow conditions, (2) present operating conditions, (3) increased Aitkin area flood protection, and (4) Twin Cities low-flow supplement. Additional analysis will be made of these four operating plans plus additional operating plan variations.

Bank Erosion Control on Six Headwaters Lakes

No structural improvements or changes in lake operation are recommended to protect large expanses of shoreline, although protection of individual properties may be justified. The current plans of operation for the six headwaters lakes have stabilized or caused a decline in erosion on each of the six lakes. Recent detailed studies of erosion on Lake Winnibigoshish concluded that erosion declined during the period 1939 to 1969. Study findings may be summarized as follows:

a. Fifty-six percent of the total erosion may have occurred during only 3 years (1943, 1944, and 1950).

b. Approximately two-thirds of the total erosion occurred in the first 12 years of the period 1939-1969.

c. There was an overall decline in potential erosion.

No further studies are recommended except as this problem relates to headwaters lake operation.

Erosion Problems Downstream of Pokegama Dam

No economically feasible solution was identified for the problem area located about 10 miles downstream of Pokegama Dam near Blackberry, Minnesota. No structural measures are recommended for this area which, over the past 20 years, has experienced several channel changes that have been determined to be part of natural river processes. No additional study is recommended for the problem.

White Oak Lake Water Levels

No further action is recommended for stabilizing the White Oak Lake water levels. A proposed dam at Days High Landing appears to be economically feasible and would help stabilize White Oak Lake levels, but the Minnesota Department of Natural Resources does not currently support this development.

Black Bear and Miller Lakes Flood Problem

A dam or closure structure that would prevent backup flooding from the Mississippi River would give the best flood protection for this area. However, the benefit-cost ratio for the dam is marginal. The only alternative currently feasible is flood insurance, adopting floodplain regulations, and restricting further development of the floodplain area around these two lakes. The dam (closure structure) should be evaluated further to determine whether it is economically feasible.

Headwaters Lakes Perimeter Dikes

The 28 perimeter dikes located around Winnibigoshish, Pokegama, Sandy, and Pine River Lakes are required to maintain the desired headwaters lakes operation schedules. These dikes are in varying states of repair; some are satisfactory, while others have serious seepage and possible stability problems. Initial inspections were limited by study funds, but these dikes should be scheduled for detailed inspection and testing to determine what recommendations should be made.

Whitefish Lake Channel Obstructions and Marking

Permanent connecting channels at six locations in the Whitefish Chain of Lakes are economically feasible. These six connecting channels could be dredged to provide adequate width and depth at low water elevations. The channels would be paralleled, as required, by rock jetties to insure permanence and to provide shore access for fishing. This alternative is recommended for further investigation.

Leech Lake Dam Inlet Channel Restrictions

The present Leech Lake inlet channel could be dredged to improve the hydraulic capacity of the Leech Lake Dam. The flow capacity of the dam is less than it was when the dam was originally constructed in 1884. Shoaling in the vicinity of the Leech Lake entrance is the primary obstruction, and removal of about 186,000 cubic yards of material is necessary. This alternative is recommended for further investigation.

Leech Lake Marsh Channel Cutoffs

The development of marsh areas in the 4-mile reach below Leech Lake Dam is marginally not economically feasible. A reevaluation of this alternative is recommended before any detailed analysis is made. A subimpoundment could be developed in Leech Lake to improve fish and wildlife habitat and to offset earlier environmental losses associated with previous channel dredging. The proposed development in the Sugar Point bog area is recommended for further study.

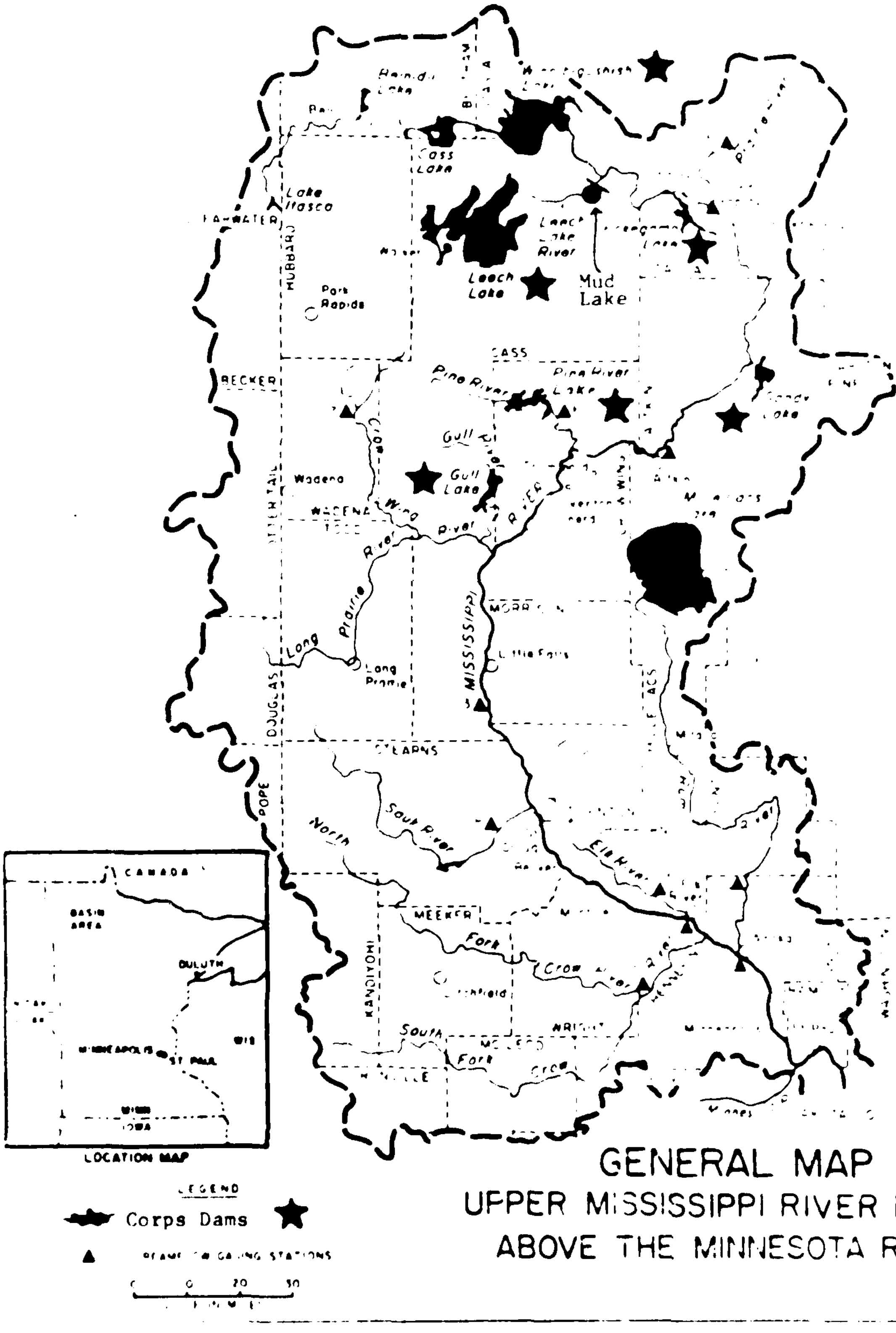
Aitkin Area Flood Problems

No economically feasible permanent flood protection plan exists for the city of Aitkin or for downstream rural Aitkin. Flood insurance, the existing Aitkin diversion channel, flood forecasting and warning, and maintenance of the existing Aitkin emergency dike are measures which would reduce local flood losses. The report recommended that local residents in the affected area consider purchasing flood insurance, and that floodplain zoning and regulations be developed and enforced to control further floodplain development. It also recommended that the feasibility of developing a modified flood control operating plan for Aitkin be evaluated in conjunction with a review of several lake operating plans. These conclusions are currently under review and may be modified as studies progress.

ECONOMIC DAMAGE SURVEYS

A damage survey conducted on 19-22 June 1978 contacted the 107 known Leech Lake commercial property owners. The survey was intended to aid in the evaluation of lake operating plans by providing a good estimate of economic losses caused by high and low lake levels. The results of the survey are as follows:

Interviews	Damage
14	High water damage only
23	Low water damage only
52	Both high and low water damage
18	No damage
107	Total interviews



GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

FEBRUARY 1978

PROGRESS REPORT

This is the fourth progress report on the "Mississippi River Headwaters Lakes in Minnesota" study. The report presents information on study progress and upcoming activities in the study area.

CURRENT STATUS

A draft preliminary report on the headwaters lakes study will be completed in February. The report will review possible solutions to problems that were identified in our first progress report. The major concern of the study - possible changes in headwaters lake operating plans - is not fully addressed in the draft report. When additional work has been completed, this part of the study will be presented to the public for review and input.

MEETINGS

No significant meetings were scheduled or conducted since the last progress report was issued in October 1977. Workshops will be scheduled in the near future to review the February 1978 draft report and to review lake operation study results.

ECONOMIC DAMAGE SURVEYS

Damage surveys were conducted on Pokegama and Sandy Lakes and in the rural Aitkin area in 1977. Elevation-damage curves and damage-frequency curves were developed for the areas. The information gathered on Pokegama and Sandy Lakes was used to develop similar curves for Winnibigoshish, Leech, Pine River and Gull Lakes. The results of these damage surveys will be publicized at future workshops and will be used in the current computer evaluation of lake operating plans.

The following table summarizes the average annual damages determined by the surveys. The figures are based on the present headwaters lake operating plans and current price levels.

Site	Annual damage
Lake	
Winnibigoshish	$15,050
Leech	61,600
Pokegama	49,000
Sandy	42,650
Pine River	75,000
Gull	52,400
Subtotal	295,700
Aitkin area	
Agricultural	153,300
Nonagricultural	48,800
Subtotal	202,100
Total	497,800

This information may be revised when more detailed field investigations have been completed.

OTHER STUDIES

The Minnesota Pollution Control Agency, in conjunction with the University of Wisconsin and Bendix Aerospace Systems, completed a land satellite imagery study in November 1977. The study produced colored images of much of the Mississippi River Headwaters area. Specific land use and water quality parameters were color coded on 1:250,000 scale maps.

The Region 5 Regional Development Commission in Staples, Minnesota, also completed a water quality study in 1977 using land satellite imagery. This study was conducted by Bendix Aerospace Systems and attempted to identify lake water quality parameters in the area. That portion of the Mississippi River Headwaters study area in Cass and Crow Wing Counties was included in the project.

The city of Minneapolis is conducting a feasibility study to determine if groundwater can be used to supplement the present municipal supply which comes entirely from the Mississippi River. Minneapolis is looking at a groundwater source to provide better water quality as well as an alternate source of supply.

The Bureau of Outdoor Recreation released its final report and environmental impact statement on the Upper Mississippi Wild and Scenic River Study in October 1977. The report recommends adding 12 segments totaling 353.3 miles of the Upper Mississippi River to the National Wild and Scenic River System. The upper 10 river segments totaling 300.3 miles would be managed by the National Park Service, and the lower 2 segments totaling 53 miles would be managed by the State of Minnesota. President Carter has proposed legislation that would put the report recommendations into effect, but Congress has not acted on the proposal.

HYDROLOGIC OUTLOOK-1978

The current forecast is for a return to a normal or above normal runoff situation in 1978. Headwaters lake levels were near normal in January of this year, with a net release from all six lakes of 2,180 cubic feet per second (compared with the 1976-77 drought period release rate of 270 cubic feet per second).

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

OCTOBER 1977

PROGRESS REPORT

This is the third progress report on the "Mississippi River Headwaters Lakes in Minnesota" study. The intent of this report is to inform interested parties on the study progress.

CURRENT STATUS

The St. Paul District is evaluating possible solutions to problems that were identified in our first progress report. Study efforts so far have concentrated on some of the lesser problems identified with the operation of the six headwaters lakes. Evaluation of different operating plans is getting under way, using the services of the University of Minnesota's St. Anthony Falls Hydraulic Laboratory.

MEETINGS

No significant meetings were scheduled or conducted other than those identified in our July 1977 progress report. A letter report was provided to the city of Aitkin, Minnesota, on 26 August 1977 summarizing possible non-structural and structural solutions to Aitkin's flood problems. No economically justifiable structural solutions could be identified at this time, but later input from Mississippi River headwaters lake operation benefit-cost studies could change these results. The benefit-cost studies are in progress.

ECONOMIC DAMAGE SURVEYS

Preliminary results of the June 1977 economic damage survey on Pokegama Lake are 85 percent complete. Initial findings indicate that: (1) approximately 60 houses around the lake will receive some water damage from a 1-percent chance (100-year) flood, (2) businesses (resorts) have decreased from about 25 in 1962 to only 12 in 1977, and (3) principal damage from high water on Pokegama Lake is from shoreline erosion.

The Aitkin Agricultural Area Surveys conducted in June and August 1977 indicate: (1) the area is primarily involved in livestock operations as opposed to crop production, (2) fairly low flows flood some agricultural land, and (3) the 1975 flood (13-year flood) reduced some farmers' incomes by as much as one-third. The results of this study are only about 60 percent complete.

A field survey of Sandy Lake properties was conducted by boat during the last week in September. Pictures and approximate elevations were obtained for more than 1,000 individual homes or cabins and approximately 12 businesses. Sample interviews with lakeshore residents are scheduled for later in October 1977.

CONTRACTS

A professional services contract was negotiated with the University of Minnesota, St. Anthony Falls Hydraulic Laboratory in September 1977. The University will attempt to develop a computer model to evaluate and compare effects of several different operating plans for the Mississippi River Headwaters Lakes.

MEMBERSHIP CHANGE

Mississippi River Headwaters Association District 2 Director, Gary Jerrips, representing the Big Sandy-McGregor area, recently moved to Montana. The Association is looking for a replacement.

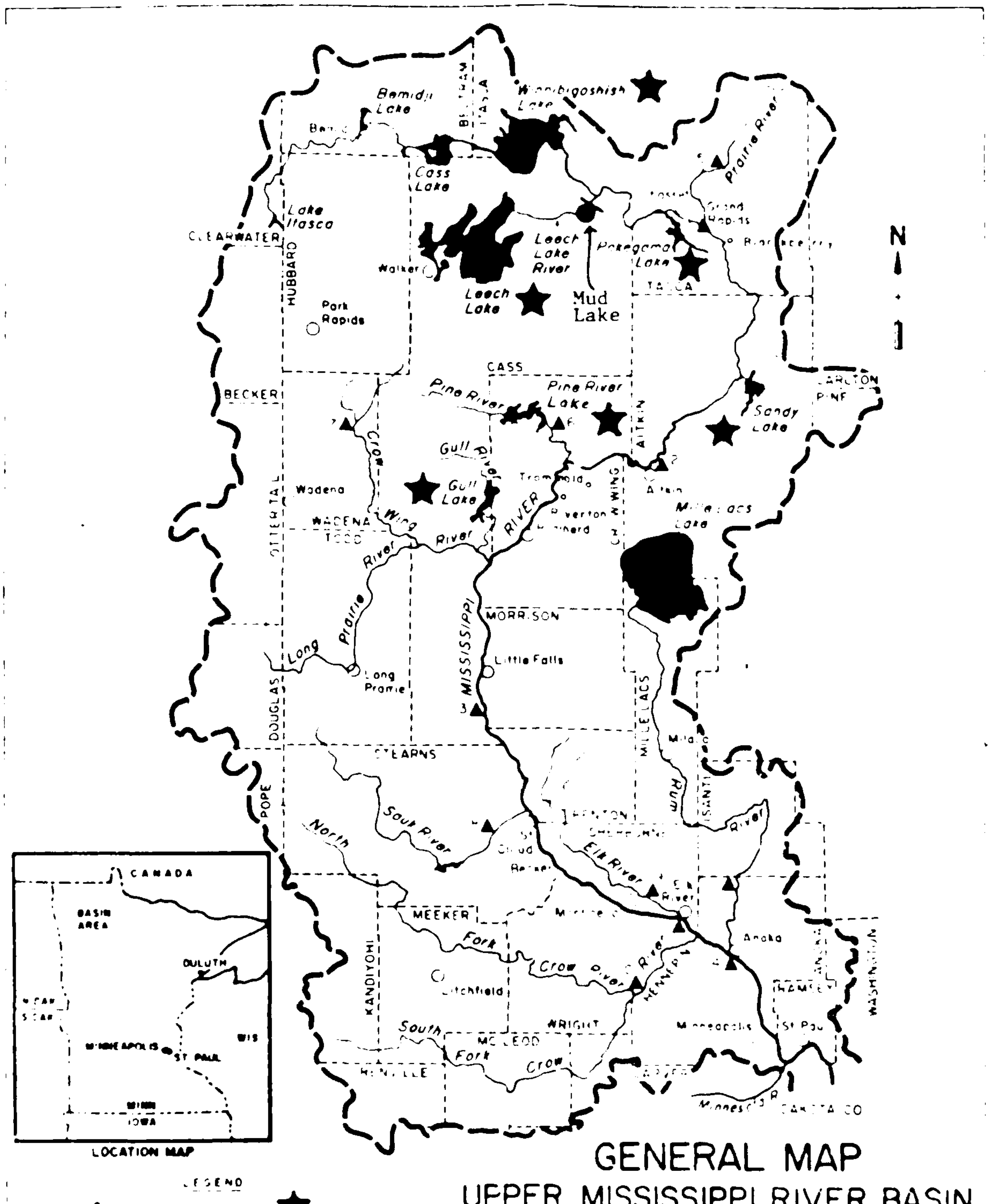
HIGH WATER LEVEL SUMMARY

The following tabulation of high water levels may be of interest to lake area residents. The 1-percent (100-year) and 10-percent (10-year) chance floods are taken from newly developed high water level frequency curves for each Mississippi River headwaters lake. A similar tabulation of low water levels will be prepared as soon as low water frequency curves are developed.

Summary of elevation vs frequency for the six Mississippi River Headwaters Lakes

Lake	Desirable summer operating limit	High water elevations: 10-percent chance (10-year)*	1-percent chance (100-year)*	Maximum observed in 1950
Winnibigoshish	1299.44	1301.5	1302.9	1303.17
Leech	1294.90	1296.3	1297.2	1296.81
Pokegama	1273.67	1277.3	1278.2	1277.32
Sandy	1216.56	1221.6	1223.9	1224.82
Pine River	1229.57	1231	1232.8	1231.41
Gull	1194.0	1194.7	1195.4	1195.[illegible]

* Based on 41 years of record, 1936-1976.



GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN ABOVE THE MINNESOTA RIVER

LEGEND

Corps Dams ★

▲ STREAMFLOW GAGING STATIONS

0 10 20 30

SCALE IN MILES

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

JULY 1977

PROGRESS REPORT

This is the second progress report on the "Mississippi River Headwaters Lakes in Minnesota" Study. The report presents information on study status and upcoming activities in the study area.

PLAN OF STUDY

The January 1977 Plan of Study for the Mississippi River Headwaters Lakes in Minnesota was approved by the Office, Chief of Engineers in Washington, D.C. on 29 April 1977. The study activities as outlined in the plan of study can now proceed, subject to available funds.

Meetings

An open meeting was held with the Mississippi Headwaters Association on 15 June 1977 at Walker, Minnesota. Approximately 30 people attended. The principal objectives of the meeting were to (1) discuss study progress to date, and (2) obtain the views of the Mississippi Headwaters Association regarding preliminary study findings and future study efforts.

On 30 July 1977 an open meeting will be held with lakeshore property owners on Black Bear-Miller Lakes in Crow Wing County, Minnesota. The meeting will be held at 2 p.m. in Crosby, Minnesota, to discuss study findings and recommendations on the Black Bear-Miller Lakes flood problem.

In addition, two meetings are scheduled for 3 and 4 August to discuss the results of another study in the Mississippi River headwaters area. The parallel study has developed an updated master plan for the Corps-operated recreation areas including each of the Mississippi River Headwaters Lakes. The plan is now in draft form; therefore, the meetings are designed to obtain public input for the final report. Locations and times for the public meetings are as follows:

a. Wednesday, 3 August, 7 p.m.
Council Chambers, City Hall
Grand Rapids, Minnesota

b. Thursday, 4 August, 7 p.m.
Crow Wing County
Social Service Building
Fourth and Laurel
Brainerd, Minnesota

Flood Damage Surveys

In June 1977, Corps of Engineers personnel conducted field surveys damage interviews relative to water levels on Pokegama Lake. Photo rage and elevation data were obtained for over 900 residential and mercial properties around the lake and sample interviews were con- ed with lakeshore property owners. Pokegama Lake was selected to surveyed first because of its moderate shoreline length, the high centration of dwellings per mile of shoreline, and the high propor- t of complaints about lake operation which originated in the area. remaining headwaters lakes areas will be surveyed later as time and ds permit.

Along with the Pokegama Lake survey, a field survey of flood damage the Aitkin area is in progress. Principal efforts will be directed ard determining realistic urban and rural flood damage estimates.

STUDIES

The Department of Housing and Urban Development will soon conduct itional flood insurance studies for the Mississippi River in Aitkin nty. The studies will expand on the 100-year and standard project dplain delineation report prepared in 1975 for Aitkin. The studies l establish actuarial rates for both urban and rural Aitkin County as by 1979, which will permit a more equitable distribution of insur- e costs to those participating in the flood insurance program.

Cultural and archeological studies will be started on Leech, egama, Pine River (Whitefish chain), and Gull Lakes in calendar year . The studies will identify shoreline archeological sites, deter- their extent, evaluate their potential for inclusion in the National ister of Historic Places, assess the effects of erosion, and make mmendations for mitigation. The studies will be similar to those ducted for Sandy and Winnibigoshish Lakes.

A 2-year study of the Leech Lake fishery will begin in October 1977. study will be conducted by the Minnesota Department of Natural Re- rces and funded by the St. Paul District. The primary purpose of the hery study is to determine the optimum range of water levels for fish duction, with the emphasis on northern pike. The effect on walleye other species will also be considered in the study.

MEMBERSHIP DIRECTORY
FOR THE
MISSISSIPPI HEADWATERS ASSOCIATION*
as of September 23, 1976

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Terry McArdle 665-2501
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Deer River Area
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District 6

Pokegama Lake Area
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1721 LaPlant Road
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Grand Rapids Area
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Grand Rapids, MN 55744

OFFICERS

President: Claude F. Titus

Vice President: Merrill E. Stodghill

Secretary-Treasurer: George A. Rossman 326-6623
406 Pokegama Avenue North
Grand Rapids, MN 55744

* The association was formed to provide effective two-way communication between the Corps of Engineers and the public concerning the current headwaters area studies.

MISSISSIPPI RIVER
HEADWATERS LAKES STUDY

ST. PAUL DISTRICT CORPS OF ENGINEERS
1135 U.S. POST OFFICE
ST. PAUL, MINNESOTA 55101

MARCH 1977

PROGRESS REPORT

This is the first progress report on the "Mississippi River Headwaters Lakes in Minnesota" Study. This study was revised in 1976, due to renewed interest by headwaters lakes area residents and downstream interests in the operation of the dams that control six Mississippi River headwaters lake areas. These lake areas are: Winnibigoshish, Leech, Pokegama, Sandy, Pine River and Gull.

The six dams were originally built in the late 1800's and early 1900's for the purpose of supplying water for Mississippi River navigation needs. The need for navigation has diminished over the years and recreation, flood control, water supply, fish and wildlife, and other interests are in competition over how the dams should be operated.

STUDY HISTORY

The Mississippi headwaters has a long history of conflict. Major adjustments in the operation of the dams were made as early as 1931, and again in 19.., as the result of public hearings that were held in the area. The present headwaters study was actually authorized in 1945, with the prime interest being that the operation of the six headwaters dams be reviewed to determine if the present plan of operation provided maximum benefits. Due to limited funding, very little was accomplished on the study until a computer analysis was conducted during 1962-1964. The results of this study were inconclusive.

The study was subsequently expanded to include consideration of a dam on the Mississippi River near Days High Landing, restoration of marshes on the Leech Lake River below Leech Lake Dam and erosion control on the headwaters lakes. A preliminary report was completed on the Leech Lake Marsh proposal in 1966, and another report was completed on the Days High Landing proposal in 1972. Both reports indicated feasible projects, but neither project was ever authorized. Studies and work on erosion control on headwaters lakes were limited to recent efforts by the U.S. Forest Service on Lake Winnibigoshish.

The most recent study efforts starting in 1976 consisted of preparing a plan of study outlining future study efforts and holding informational meetings in the headwaters area. The following planning objectives were developed as a result of this effort.

a. Develop optimum operating plan for the six headwaters dams (on a system basis) in the interest of:

(1) Stable water levels for lake docking facilities.

(2) Wild rice production upstream and downstream of the dams, water supply, fish and wildlife conservation, hydropower and power plant cooling water needs, and navigation.

(3) Bank erosion control on the six headwaters lakes.

(4) Erosion control downstream of Pokegama Dam.

b. Control water levels in the White Oak Lake area for wild rice production and fish and wildlife conservation.

c. Reduce flood damages on Black Bear and Miller Lakes near Riverton, Minnesota.

d. Develop an optimum plan for the headwaters lakes perimeter diking system.

e. Remove channel obstructions to recreational craft in Whitefish Lake Chain.

f. Remove restriction in Leech Lake Dam inlet channel.

g. Marsh restoration downstream of Leech Lake Dam.

h. Flood damage reduction in the Aitkin, Pine Knoll, and Cedar Brook areas.

STUDY ORGANIZATION

A State-Federal steering committee has been formed to provide coordination and direction to the study and to monitor progress. The Mississippi Headwaters Association was formed by a group of concerned citizens in the headwaters area to provide effective two-way communication between the Corps and the people of the headwaters area. The board of directors from this organization consists of 12 members from representative locations in the Upper Mississippi River Basin. Mr. Carl Stephan, Corps of Engineers, is the study manager.

STUDY PROGRESS

The January 1977 Mississippi River Headwaters Lakes Plan of Study (POS) was submitted to our Chicago office for review and approval on 7 January 1977. This is the study stage I report. It appears that several minor changes will be made to the POS as a result of comments by

the Chicago office. The POS will be further reviewed by the Office of the Chief of Engineers in Washington for final approval; however, work is already in progress to develop background information for the stage II report which will evaluate alternative solutions and costs for the identified problems in the POS.

SUPPORTING STUDIES

The study to update the Master Plans for Public Use Development and Resource Management for the six headwaters lakes is progressing well. Part 1 of the report has been completed, subject to some revision of plates and other data. This portion of the report describes, analyzes and evaluates existing conditions concerning recreation opportunities at the six Corps headwaters areas. Part II of the report, which should be completed late in 1977, will recommend proposed courses of action for facility development and resource management for each of the six Corps recreation sites.

A cultural and archeological resources investigation of the Lake Winnibigoshish shoreline will be accomplished in 1977. This investigation will identify shoreline archeological sites, determine their extent, assess the effects of erosion on the sites, evaluate the potential of the sites for inclusion in the National Register, and make recommendations for mitigation.

A similar cultural and archeological investigation will be started on Sandy Lake in 1977. This study will be conducted in a similar fashion to the Lake Winnibigoshish study with the same general objectives.

An aerial survey contract for color infrared imagery of the Mississippi headwaters lakes area was completed in 1976. The resulting photography is available at 1:36,000 scale (1 inch = 3,000 feet) on 9 x 9 inch contact prints, on black and white internegatives, and on color infrared transparencies. The photography will be used in connection with future economic damage surveys around the headwaters lakes and with related environmental studies.

Photo interpretation of infrared imagery of the Leech Lake shoreline is scheduled for 1977 by the St. Paul District. Utilizing the color infrared photographs obtained during the summer of 1976, the study will identify wetlands and other important vegetation and land and water uses. The study findings will be utilized in evaluating the effects of possible changes in lake operating plans on wetlands, wild rice, and other vegetation.

MEETINGS

A meeting was held in the Aitkin County Highway Building on 12 January 1977 to review available survey and other graphic data on the Pine Knoll area downstream of Aitkin. The Aitkin Drainage and Conservancy District, the Mississippi Headwaters Association (District Director), Aitkin County Extension Service, Aitkin County Soil and Water Conservation District, Aitkin County Highway Department, and the St. Paul District, Corps of Engineers were all represented at this meeting.

WORKSHOPS

The January 1977 Mississippi River Headwaters Lakes Plan of Study indicates that area workshops will not be held prior to December 1977. In light of the 3 January 1977 request by the Mississippi Headwaters Association, workshops will be scheduled for June and July 1977, if possible.

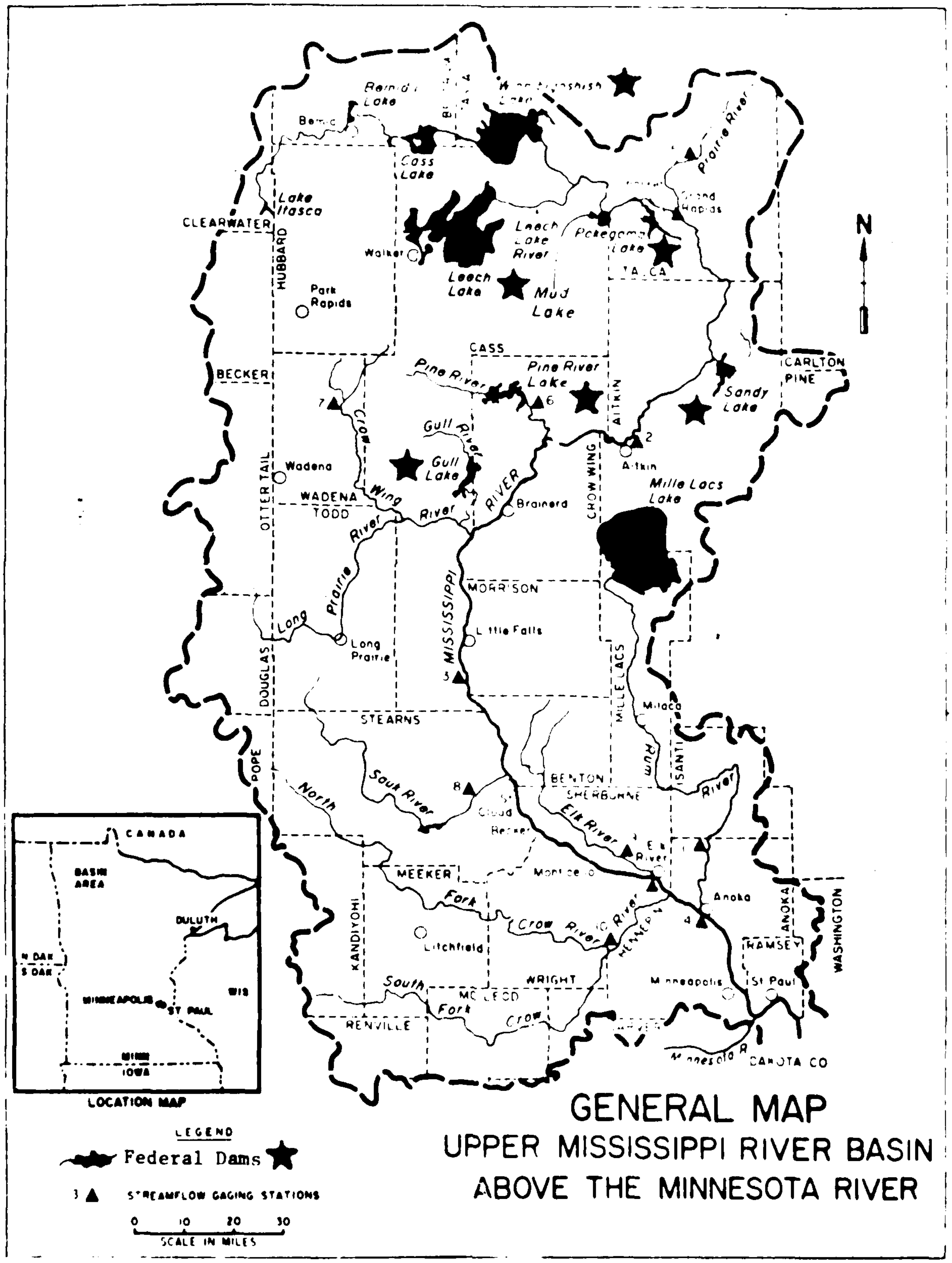
Workshops for the supporting Headwaters Lakes Recreation Master Plan Study are tentatively scheduled for April 1977. These workshops will be held in the maintenance building located at each of the Mississippi headwaters lakes damsites and will examine the information developed in Part 1 of the Recreation Master Plan. A separate announcement will be issued outlining the specific date, time and place for these workshops.

FUTURE PROGRESS REPORTS

Additional progress reports will be mailed to you as the study continues. The progress reports will keep you aware of study accomplishments and of your opportunity to participate in public meetings and workshops.

If you do not wish to be retained on our mailing list, or for further information, please contact:

District Engineer
St. Paul District
U.S. Army Corps of Engineers
ATTN: Urban Studies Section
Planning Branch
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101



GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER

STAGE 3 REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

INDIAN WATER RIGHTS -
DEVELOPMENT OF CONSERVATION PLAN

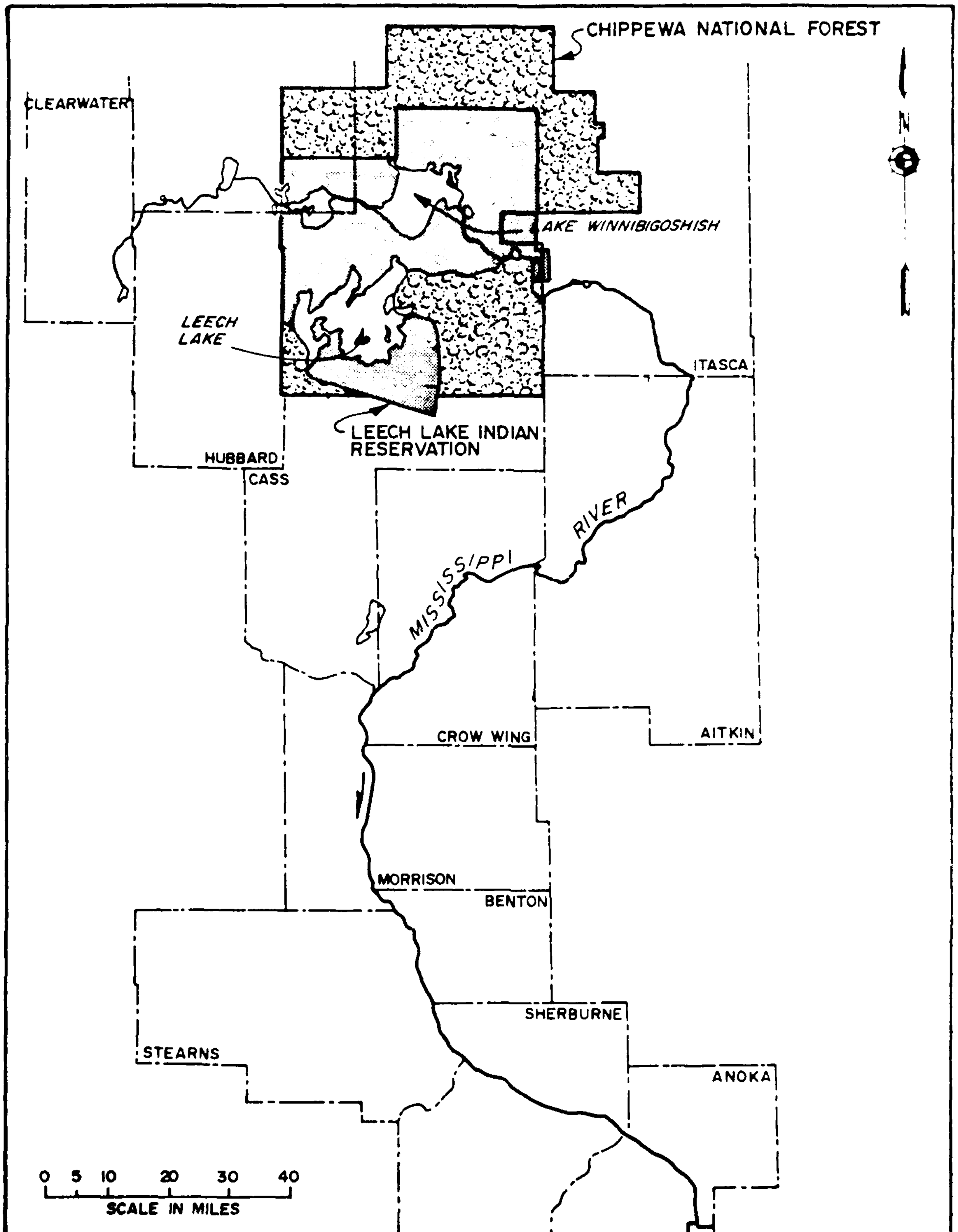
APPENDIX F

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

TABLE OF CONTENTS

BACKGROUND

The Mississippi River Headwaters area contains all or part of three Chippewa Indian Reservations: Leech Lake, White Earth, and Mille Lacs. Only the Leech Lake Indian Reservation is affected by the operation of one or more of the headwaters lakes (Winnibigoshish and Leech Lakes; see attached map).



LEECH LAKE
INDIAN RESERVATION
LOCATION MAP

The Leech Lake Indians were involved in the District's coordination effort throughout the course of this study. This effort is reflected throughout Appendix E, "Public Participation and Coordination."

The prime concern of the Leech Lake Indians with regard to operation of the Winnibigoshish and Leech Lakes centers around their unique legal status, which is reflected in three major points cited in a 26 June 1980 letter to the District Engineer:

> "1) The United States is the legal trustee of the Indian tribal estate.
>
> 2) The legal nature of any trust relationship is characterized by the principle that the administrator of a trust (the fiduciary) must, in discharging his duties, subjugate his own interests to those of the beneficiary. The conduct of the executive branch in dealing with the Indian trust estate must conform to the highest fiduciary standards. The preservation of the integrity of the trust estate must, in many cases, take precedence over the welfare of the general public, thus rendering the 'greatest good for the greatest number' theory inoperative when viewed in the context of the federal-Indian trust relationship.
>
> 3) The trust estate of the Leech Lake Band of Chippewa Indians is not limited to its diminished land holdings. The Band also possesses legitimate ownership interests in the fish, game, wild rice and other harvestable resources within the Reservation. In addition, although unquantified at present, the Tribe undoubtedly possesses ownership interests in the water resource of the Reservation. All of these 'properties' are included in the Indian trust estate and come under the trusteeship of the United States government."

The three points are of concern in evaluating alternative operating plans for the six Mississippi River Headwaters Lakes. The desires and needs of the Leech Lake Tribe must be accounted for during plan evaluation. The Corps acknowledges the special status of the Indian under the law but is not in a position to define or weight the significance of Tribal water rights in the Mississippi Headwaters area. The matter of Indian water rights falls under the jurisdiction of Congress and the Federal courts, and is outside the scope of this study.

Congress authorized construction of the headwaters lakes dams by the 14 June 1880 and 2 August 1982 Rivers and Harbors Acts, and in 1888 directed the Secretary of War to establish regulations governing control of water levels and discharges. The regulations established at various times since then are broad and provide the District Engineer with considerable flexibility in control of the Mississippi River Headwaters Lakes. In keeping with this flexibility, the Corps of Engineers has regulated the six headwaters lakes to accommodate all public (including the Leech Lake Tribe) interests within the lake flowage rights purchased in the late 1800's and early 1900's. The authority for the present study is contained in a 7 June 1945 resolution by the Committee on Rivers and Harbors of the House of Representatives.

The Indians maintain that they vigorously opposed the original dam construction and that the dams were authorized and constructed by order of Congress in spite of their protests. The Indians also maintain that the Leech Lake Band was promised a large sum of money annually, and in perpetuity, for the damage that resulted from the dam construction. Although they acknowledge that a group of their band accepted a lump sum damage payment after 1890, overall, the members of the Leech Lake Band do not believe they have been fully compensated for the loss of their lands and changed conditions.

CURRENT STUDY

The tribe's interest in the study increased greatly after the District prepared and circulated a preliminary draft phase 2 report summary, dated February 1978. The Tribe was concerned that one of the four plans referred to in this report (a low-flow release plan) would drastically reduce lake water levels and damage fish and rice populations. The Tribe is economically dependent on these resources and will oppose any plan which would adversely affect them.

A second draft stage 2 report by the District in September 1979 led to additional expressions of concern by the Tribe. Included in the concerns was a request that the Corps evaluate an operating plan that would optimize lake levels for fish and wildlife resources and wild rice production.

It was subsequently agreed between the Leech Lake Band and the Corps that an operating plan would be developed and evaluated that would optimize the production of natural resources that are native to the headwaters lakes within the trust estate of the Leech Lake Band. The trust estate for the purpose of this evaluation is the Leech Lake Reservation boundary. The operating plan so evaluated was referred to as the "conservation plan."

It was further agreed that the headwaters study would attempt to evaluate the effects of alternate operating plans on the following items:

- The annual yield of wild rice.
- Fish habitat and propagation areas.
- Habitat of furbearing animals and waterfowl.
- Cranberry bogs and other related resources.
- The economic impacts of all of the above on the Leech Lake Band.

It was also agreed that the base data needed to develop evaluation relationships would be collected jointly by the Corps and the Tribe.

ECONOMIC PROCEDURE

As a first step, a literature search was conducted by the Corps and the director of the Leech Lake Department of Natural Resources. The search found little available information on any of these resource topics. The two most useful publications turned up in the search were (1) the Minnesota Department of Natural Resources' study of the Leech Lake Fishery prepared in December 1979 and (2) a U.S. Fish and Wildlife study of wild rice prepared in 1957. These two studies specifically correlated lake levels and production.

AD-A130 355 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY APPENDICES(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82 8/8

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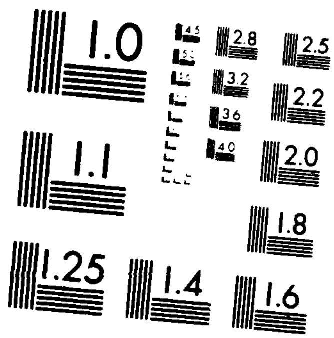


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

The 1979 fishery study reached the following conclusions:

1. No relationship could be demonstrated between population, size, or class strength of northern pike and water levels over the past 50 years. However, a water level of 1294.0 by 15 April appears to be optimal for providing maximum spawning area for northern pike in Leech Lake. This level is also satisfactory for walleyes.

2. Leech Lake water levels between 15 April and 15 May should be stable or rising to prevent exposure of eggs or young of both species or stranding of northern pike in spawning areas.

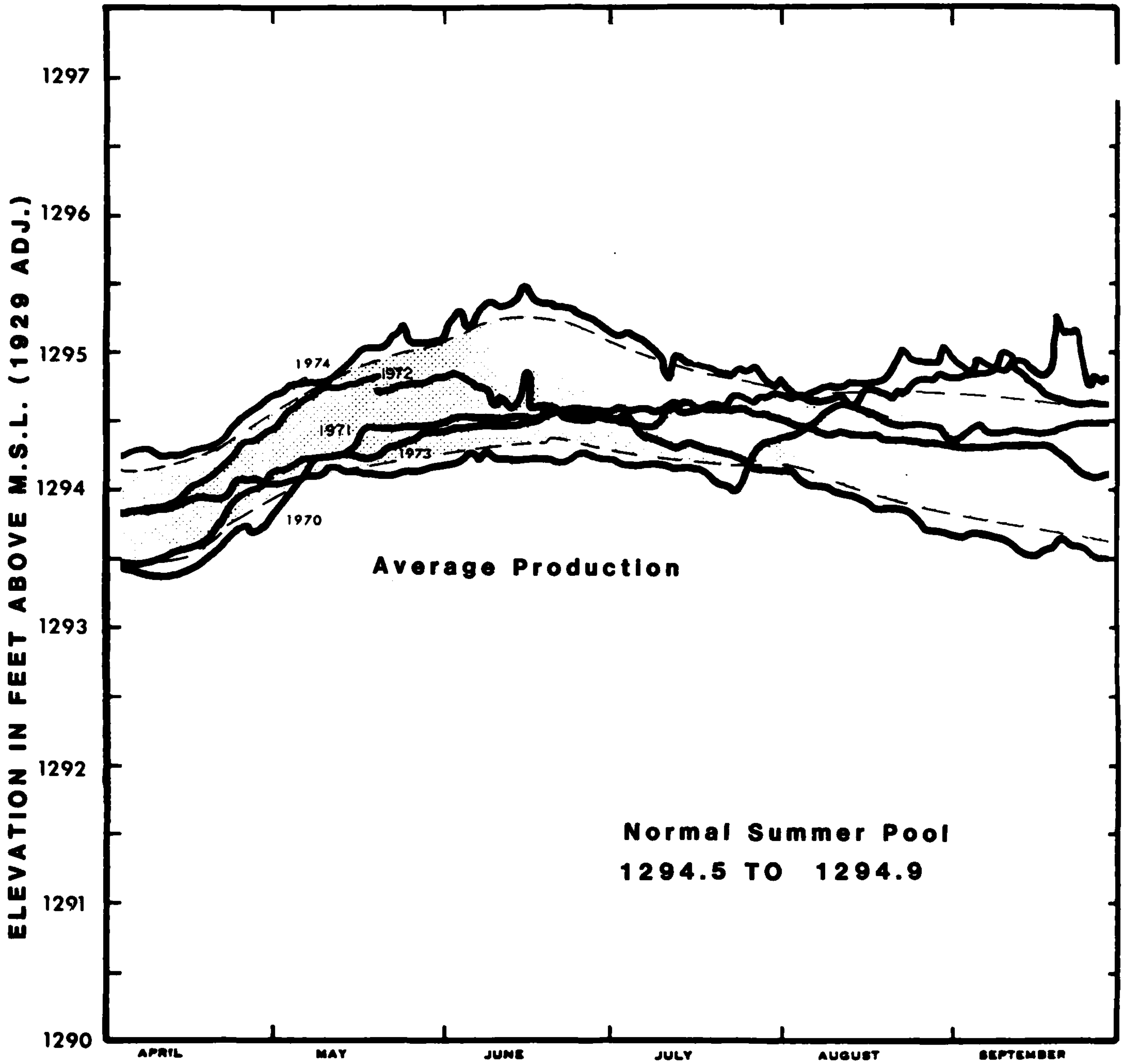
3. In unusual years with late spring warmup, the period of stable or rising water levels should continue until spawning has been completed or until 25 May.

Information from the 1957 U.S. Fish and Wildlife study indicated that a relatively high lake level was the most beneficial to wild rice production. (This conclusion does not appear consistent with those on lake levels and yields determined from the current Corps study.) Yield and production data from the 1957 report were for only 4 years (1950, 1953, 1954, 1955), too short a time period to draw firm conclusions. Additional data and time would be needed to verify the results.

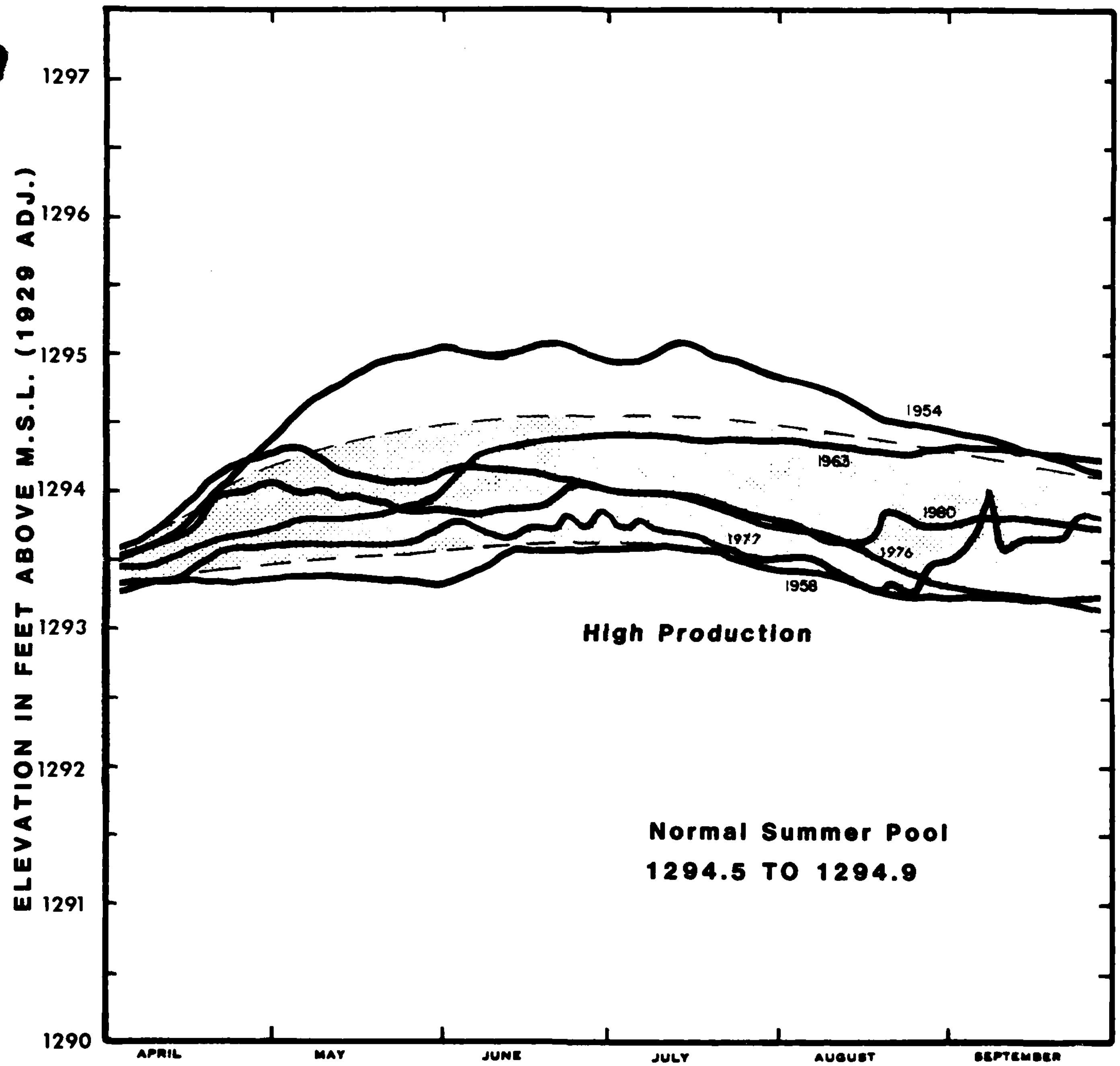
Lacking sufficient base data and ricing records, the Indian Tribe and Corps representatives jointly determined that current study effort should concentrate primarily on rice production because of its economic significance. It was the general consensus that a lake operating plan for improved rice production would similarly benefit fish and furbearer production.

Walleye production pretty well takes care of itself because of the ideal flat shoreline slopes of Leech Lake. Northern pike production is also unaffected as long as the floating bog masses remain floating during the spawning period. If water levels drop below elevation 1294.0 during April and May, northern production can be adversely affected. Generally speaking, if wild rice production is given priority, fishery and furbearers also benefit.

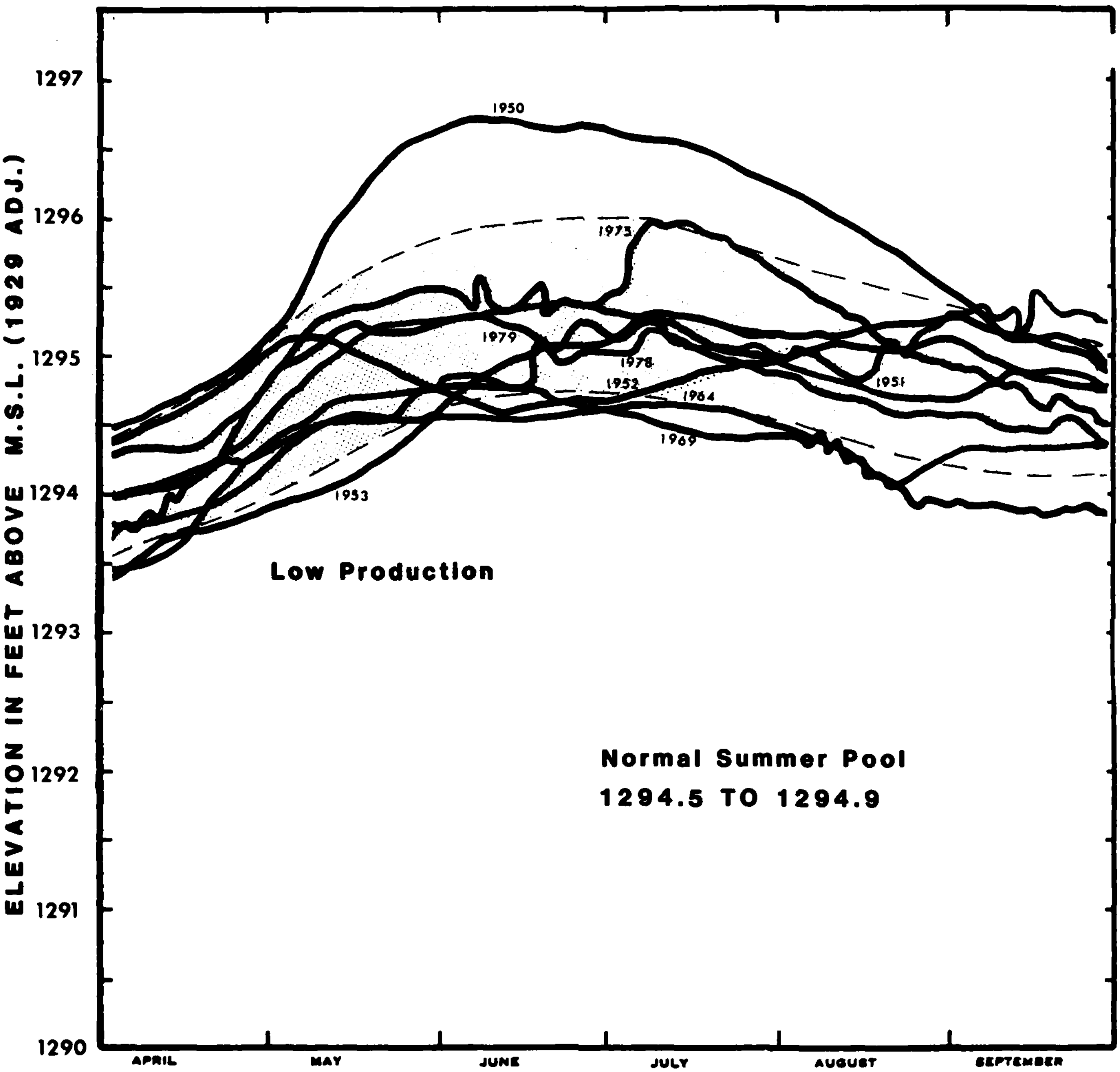
Attempts were made to correlate good-to-poor rice harvest years as qualitatively defined by the Reservation Rice Committee with observed hydrographs of Leech Lake levels for those years. A series of overlays was developed which segregated rice years into "low, good, and exceptionally good" rice production years on Leech Lake. Three bands were established from the past 30 years of ricing and hydrograph data. These bands are not mutually exclusive and are subject to several exceptions, such as a low rice year appearing in a good year band. However, the bands did enable better definition of evaluation limitations and of the problems associated with using only water levels to define good or low wild rice production. The bands also helped the Reservation Rice Committee, University of Minnesota-Agronomy and Plant Genetics, and the Corps to develop a "conservation plan" for the Mississippi headwaters study based on this generalized information.



Native Wild Rice
Leech Lake



Native Wild Rice
Leech Lake



**Native Wild Rice
Leech Lake**

LIMITATIONS AND PROBLEMS

The following limitations to developing economic benefits for wild rice production were developed as a result of the current study effort:

1. Lake operation hydrographs show a probable correlation between lake levels; changes in lake levels; and good, average, and poor rice production years.

2. Factors other than lake levels affect rice production (wind, sunlight, ricing season, temperature, insects, disease).

3. A correlation does not necessarily exist between acres of rice and rice production.

4. Available data on cultivated paddy rice does not necessarily apply to lake rice.

5. Data are not sufficient to make any reasonably accurate quantified estimate of existing rice production or to assess in quantitative terms the corresponding impact of changes in the existing operating plan levels.

CONSERVATION PLAN

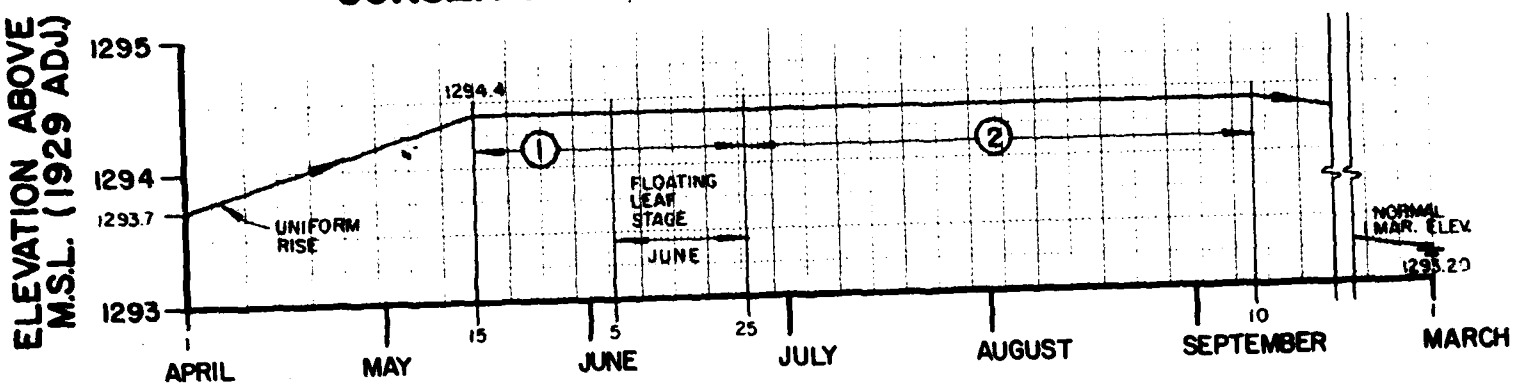
The above are limitations and problems in assessing economic impacts on wild rice and related fish and wildlife values. Therefore, it was agreed between the Tribe's Rice Committee, the Reservation Department of Natural Resources, University of Minnesota-Department of Agronomy and Plant Genetics, and the Corps that the following two actions should be pursued:

1. The parties should mutually agree on a recommended lake level plan in the Leech Lake growing season that would be identified as a "conservation" plan for the Mississippi River Headwaters study. This study is scheduled for completion in fiscal year 1982 because of funding and time constraints.

2. A 6-year base data study should be initiated to collect future information on Leech Lake rice production. (This study is currently being funded with operation and maintenance funds.) This information could be used in future evaluations, especially with any new models that were successfully developed for the current Mississippi River Headwaters study.

The conservation plan that was decided on in July 1981 is shown on the following sketch. Generally, the plan is quite similar to the present plan of operation for Leech Lake except that the conservation plan's summer level would be at the low side of the current 0.4-foot summer operating range. Attempts would be made to limit lake fluctuations as indicated on the sketch while not exceeding a combined Winnibigoshish-Leech Lake maximum downstream discharge of 2,500 cfs.

CONSERVATION PLAN - LEECH LAKE



CALENDAR YEAR

NOTES

1. ALLOW MAX. RISE OF 2" IN 48 HOURS BUT THEN STABILIZE AND BRING BACK DOWN, DURING THIS PERIOD.

2. CAN WITHSTAND UP TO 6" RISE IN 48 HOURS DURING THIS PERIOD.

2500 CFS COMBINED MAXIMUM OUTFLOW FROM WINNIBIGOSHISH AND LEECH WOULD STILL BE IN EFFECT.

RESULTS

Some additional modifications were made to the Leech Lake conservation plan in April 1982 after the HEC-5 computer modeling was completed. These changes will be incorporated into future conservation plan trials as agreed to with the Leech Lake Tribe. The modifications are minor and are within the limits of the current operating plan. The modifications are as follows:

1. Attempt to stabilize Leech Lake at a level no higher than 1294.7.

2. Modify the two rules that apply to the preceding operation sketch as follows:

   a. "Allow maximum rise of 1½ inches in 48 hours, but then stabilize and bring back down during this period."

   b. "Can withstand a 1½-inch rise in 48 hours, up to 6 inches maximum."

3. Maximum combined outflow from Winnibigoshish and Leech Lakes of 2,200 cfs.

A comparison of the conservation plan with the current plan of operation is displayed in the following table. The agreed-to conservation plan is basically an attempt to refine operation within present operating limits when conditions permit.

Operating plan comparison

Item	Winnibigoshish Lake: Current plan	Winnibigoshish Lake: Conservation plan	Leech Lake: Current plan	Leech Lake: Conservation plan
Spring drawdown elevation/date	1296.94/1 March	1296.94/1 March; 1297.44/25 April; slow rise/25 April through 15 May	1293.20/1 March	1293.70/1 April, then uniform rise; 1293.20/1 March
Norma[illegible]aximum discha[illegible]	1,000 cfs	(1)	1,000 cfs	(1)
Discharge if flooding downstream	100 cfs	100 cfs	100 cfs	100 cfs
Summer elevation	1297.94 to 1298.44	1297.94 to 1298.44	1294.50 to 1294.90	No higher [illegible]an 1294.7 by 15 May if downstream conditions permit; try to keep steady after 15 May
Rate of change of discharge	Increase no more than 100 cfs/day; decrease no more than 50 cfs/day	No limit on change	Increase no more than 100 cfs/day; decrease no more than 50 cfs/day	No limit on change

(1) Combined discharge of 2,200 cfs.

STAGE 3 REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

REFERENCES

APPENDIX G

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

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